Geology
—
Browne

FIRST LESSONS IN NATURAL HISTORY.

GEOLOGY:

COMPRISING

THE ELEMENTS OF THE SCIENCE

IN ITS PRESENT ADVANCED STATE.

DESIGNED FOR THE

Use of Schools and Private Learners.

ILLUSTRATED BY ENGRAVINGS.

BY D. J. BROWNE.

"Natural History may be fundamental to the erecting and building of a true philosophy."

LORD BACON, *Sylvæ Sylvarium.*

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1832.

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TO THE

TEACHERS OF THE UNITED STATES,

WHOSE

ARDUOUS AND UNWEARIED LABORS

CANNOT

BE TOO HIGHLY APPRECIATED

AND

ON WHOM DEPENDS THE

WELFARE

OF OUR COUNTRY,

THIS WORK

IS

MOST RESPECTFULLY INSCRIBED

BY

THE AUTHOR.

PREFACE.

Geology has become an interesting and important branch of human knowledge, and is founded exclusively on observation. Availing itself of all accessible sources of information, it has already acquired an immense fund of valuable and instructive facts, which are entirely independent of the theoretical speculations, that are often built upon them; and will remain unimpaired in value, when some of those speculations have passed into oblivion.

Many have been deterred from the study of Geology, by the supposed difficulty of learning its sister science, mineralogy; but an acquaintance with the nice distinctions made by many modern mineralogists, is not necessary to gain a knowledge of the structure and arrangement of the great masses of matter which environ the globe, nor of the substances of which they are composed. He who would gain a useful knowledge of Geology, would do well to provide himself with specimens of common rocks, and the simple minerals of which they are composed, and examine their external characters and physical properties, comparing them with the description given by the best mineralogical writers. Fortunately these substances are not very numerous, and he may omit, without present inconvenience, the more rare crystallizations and varieties, so highly esteemed by cabinet philosophers; for here, as in many other instances, the received value, is in an inverse ratio to the utility. The pedantic nomenclature, and frivolous distinctions of some writers may gratify vanity with a parade of knowledge; but they are unconnected with objects of real utility, or with any enlarged views of nature.

On hearing the various names which mineralogists give to the same substance, and observing the avidity with which each new name is seized, as if it conveyed a hidden charm, the uninitiated might suppose, that he was 'journeying in the land of Shinar,' and had fallen in company with a set of masons, fresh from the tower of Babel, each

one calling the same stone by a different name, and glorying in his absurdity. Such frivolities disgust men of sense with the study of an important and interesting science; a science which has for its immediate object, the structure of the planet that the Author of nature has destined for our abode, and an acquaintance with the situation of its various mineral productions, subservient to the wants or enjoyment of man in civilized society. The advice of Cicero to the cultivators of moral science applies with peculiar force to some geologists and mineralogists of the present day. 'In these natural and laudable pursuits, two errors are particularly to be avoided; the first, not to confound those things of which we are ignorant with those we know, or rashly to yield our assent without due investigation; the second, not to bestow too much labor and study on obscure, intricate, and unprofitable objects.'

How far this little work coincides with the foregoing remarks, the author leaves it for the candid and impartial reader to decide. His object was, in preparing this work, to furnish those who are desirous of beginning the delightful study of Geology, or who, having begun, find their progress interrupted by numerous difficulties, with a plain and short outline of some of the leading subjects of inquiry, by way of a basis on which to proceed — a grand plan to work upon in rearing a superstructure of knowledge. He has availed himself of the geological works of Alger and Jackson, Bakewell, Cleaveland, Cuvier, De la Beche, Eaton, Humbolt, Lyell, Silliman, Ure, Webster, and others, from which this work is principally composed. He would gratefully receive any corrections of errors, or suggestions, with respect to improvements, particularly from teachers who may use this work.

D. J. B.

Boston, Nov. 1832.

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INTRODUCTION.

Geology* is the doctrine or science of the structure of the earth or terraqueous globe, and of the substances which compose it; or the science of the compound minerals or aggregate substances which compose the earth, the relations which the several constituent masses bear to each other, their formation, structure, position and direction. It extends also to the various alterations and decompositions to which minerals are subject.

The primary objects of geological inquiry are, then, to ascertain, by patient investigation, of what the great masses consist which compose this earth, in what manner they are arranged, and what is their probable origin. Until the sciences of chemistry and mineralogy had made considerable advances towards that state of perfection in which we now find them, geology was scarcely understood at all; and accordingly the most absurd theorists had unbounded scope for the invention of imaginary hypotheses. It is also of indispensable utility to the mineralogist in aiding him to discover the situation in which, and under what circumstances, particular minerals are to be found.

* Derived from the Greek, *geo*, the earth, and *logos*, science.

And a more important consideration presents itself. We are enabled to

"Look through Nature up to Nature's God.'

We find that, however hidden from human discernment may be the original formation and organization of the earth, its arrangement is evidently calculated to supply the wants, and gratify the desires of man; and it exhibits, though less obviously perhaps than the animal and vegetable world, the same paternal care of the All-directing Providence,

> 'Whose won'drous power
> Presided o'er Creation's natal hour.'

> 'Whose hidden but supreme control
> Moves through the world a universal soul.'

Plan of Study.

'Theories,' says an eminent naturalist, 'are more easy and more brilliant than observations; but it is by observation alone that science can be enriched, while a single fact is frequently sufficient to demolish a system.' To all this we most cordially subscribe, and earnestly recommend to the young naturalist, who, indeed will find it not only more easy and delightful, but greatly more improving, to take his first lessons from Nature by observing the animated scene which she every where displays, rather than to sit down to study descriptions given in books, or to fill the memory with the terms of a system. It is, indeed, greatly to be regretted that the study of *things* is so much thrown into the back ground, by the almost exclusive attention now bestowed upon *words*. These ought to go hand in hand, for *theory* is useless without *practice*, and *practice* cannot be advanta-

geously pursued without *theory*. Nothing can be more unreasonable than to compel a pupil to store up a number of words in his memory, which he does not, and cannot understand; while on the other hand he cannot be supposed to retain a distinct or lasting recollection of things, and facts without names and words, — the only sort of pegs upon which they can be permanently hung. Upon this principle it is surprising at how early an age children can be instructed in the most interesting parts of natural history. Therefore, let the student of geology or mineralogy provide himself with suitable apparatus and direct his way into the fields of nature, and whatever earthy substance may meet his eye, whether it be the clay of the dell, the pebble of the shore, the rock of the mountain, or the diamond of the valley, let him collect it, investigate its properties, and carefully deposit it in his cabinet, in its proper place. If he should meet with more than his immediate wants require, let him preserve them; for opportunities will readily offer themselves to exchange them for those of remote places. Let not the mere collecting of the substance, of learning its name, of investigating its properties, or of arranging it in his cabinet be his sole object; but let him note the situation or position in which it is found, study its utility and relations to the rest of the universe, and above all, let him remember that it is the work of the All-wise Creator, to whom he owes unbounded love and veneration. Such a course, if justly pursued, will direct him to the true path of science, and if duly regarded, in a moral point of view, will lead him to that of virtue and of happiness.

GEOLOGY.

CHAP. I.

On the Figure and Structure of the Earth.

It has been concluded, both from astronomical and geodesical observations, that the figure of the earth is that of a sphere, flattened at the poles, which has been considered as one of rotation, or such a figure as a fluid body would assume if possessed of rotary motion in space. The surface of the crust of the earth is irregular. In some parts it is hollowed into deep cavities, which are filled with seas, lakes, and other waters; in other places, it rises above the level of the water, and forms land, the surface of which is diversified by mountains and valleys.*

In speaking of the earth and of our knowledge of its nature, it is essential that the limited extent of that knowledge should always be had in remembrance. We are acquainted with it, only to a very considerable depth; and when it is recollected that, in proportion to the bulk of the earth, its highest mountains are to be considered merely as unimportant inequalities of its surface, and that our acquaintance does not extend in depth† more

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* The equatorial diameter is about . . .	7924	miles.
The polar axis about	7898	
Difference	26	
The equatorial circumference is about . . .	24912	miles.
The polar circumference about	24854	
Area of the whole earth about . .	197552160	square miles.
Solidity about	259660387585	cubic miles.

Density about 5 times heavier than water and nearly 4 times more than the sun.

Weight about 5920000000000000000000 tons avoirdupois.

† One of the salt mines of Fruttenburgh, Bohemia, is 3000 feet deep.

than one fourth of the elevation of these mountains above its general level, we shall surely estimate our knowledge of the earth to be extremely superficial; that it extends only to its crust.

The term *crust of the earth* therefore relates only to the comparative extent of our knowledge beneath its surface. It is not used with the intention of conveying an opinion that the earth consists only of a crust, or that its centre is hollow; for of this we know nothing. The term may not be philosophical, but it is convenient.

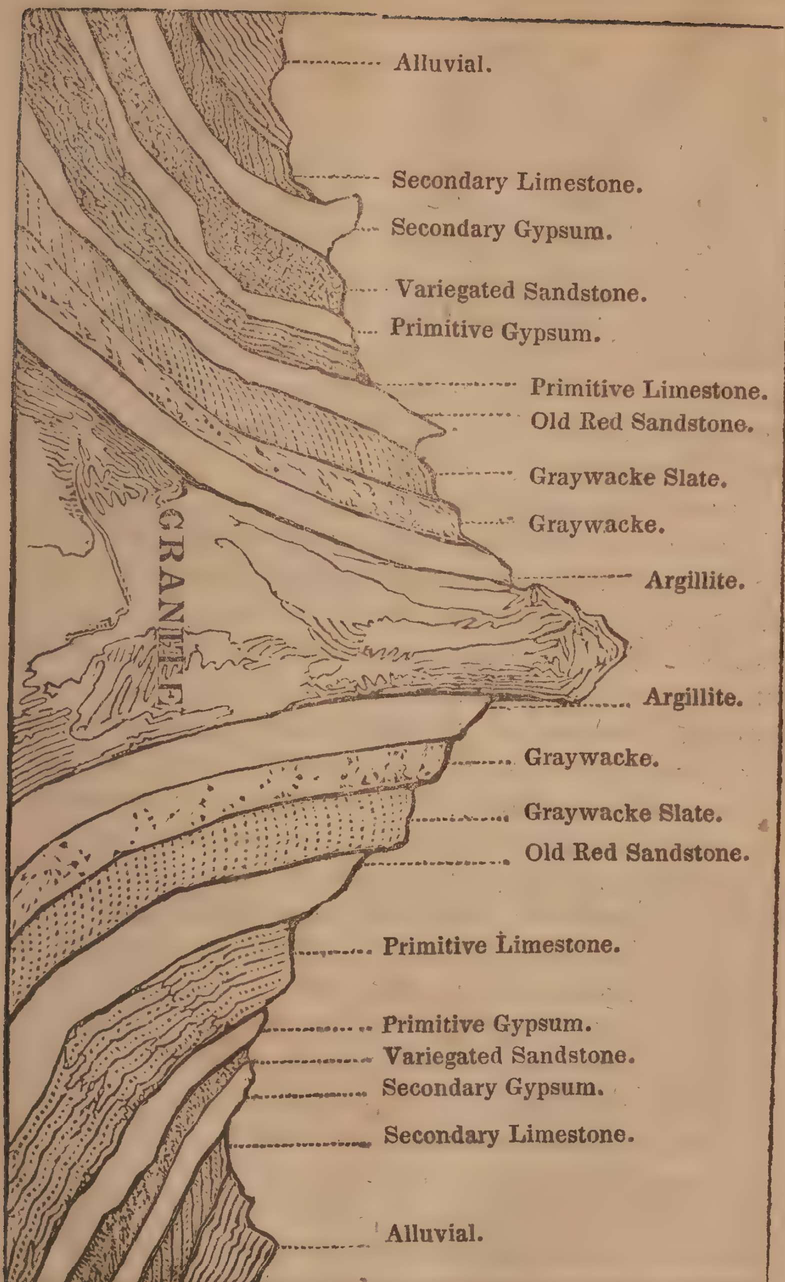
The nature of the crust of the earth is most readily studied in mountains, because their masses are obvious; and also because, as they are the chief depositories of metalliferous ores, the operations of the miner tend greatly to facilitate their study. Mountains are composed of masses which have no particular or discernable shape; or, as is more commonly the case of strata or beds, either horizontal or oblique, and sometimes nearly vertical.

The surface of the globe, considered with relation to its inequalities, is divided into highland, lowland, and the bottom of the sea. The highland comprises *alpine land*, composed of mountain groups or series of mountain chains; *mountain chains*, formed by a series of those still more simple inequalities, called *mountains:* in the former we consider their length, height, form, and connexion; the parts of the latter are the foot, the acclivity, and the summit. Lowland comprises those extensive flat tracts which are almost entirely destitute of small mountain groups. To the bottom of the sea belong the flat, the rocky bottom, shoals, reefs, and islands. It is only after a diligent study of the inequalities just pointed out, that we can with advantage undertake to explore the

means employed by nature to produce them; and the first step is to proceed to the examination of the physical causes of the slow, but unceasing changes of the globe. Observation teaches us, that most of the elevations and hollows we meet with on the surface of the earth owe their origin to the action of the atmosphere, to that of the ocean, and to volcanic fire. These powerful agents may be considered with regard to their *destroying*, and, in consequence of this destruction, with regard to their *forming* effects.

All geologists are agreed that our present continents were once covered with water. This is proved by the remains of marine animals imbedded in the strata which lie on the summits of the highest mountains. The structure of the globe, as far as we are acquainted with it from the intersections made by rivers, by the action of the sea upon the coast, and by mining operations, consists of beds of different kinds of stone, which generally increase in thickness as we descend deeper. Stratification, in its simplest form, may easily be conceived, by placing a closed book with the back resting upon the table, and raising the opposite edges a little; the book may represent a thick mineral bed, and the leaves a series of strata.* In nature we frequently find the strata much broken, and thrown out of the original position. Where any series of strata are wanting, a question naturally arises, have they been carried away by some sudden inundation, before the upper strata were deposited, or have they never extended to that place? In some instances it is certain that the strata have been carried away from particular

* The following plate represents a section of Brocken Mountain, in Hartz Forest, Germany, showing the different layers of which it is composed with their names



Alluvial.
Secondary Limestone.
Secondary Gypsum.
Variegated Sandstone.
Primitive Gypsum.
Primitive Limestone.
Old Red Sandstone.
Graywacke Slate.
Graywacke.
Argillite.
GRANITE
Argillite.
Graywacke.
Graywacke Slate.
Old Red Sandstone.
Primitive Limestone.
Primitive Gypsum.
Variegated Sandstone.
Secondary Gypsum.
Secondary Limestone.
Alluvial.

situations, as in some of the excavations which have formed valleys, in which the strata that terminated on one side of the valley may be discovered again in the hills on the opposite side. The substances of which the strata are composed, are argillaceous, calcareous, or siliceous earth, which are generally more or less intermixed or combined. The strata of clay, or argillaceous strata, being water-tight, give rise to springs, as they arrest the water that runs through the porous strata, and convey it to other situations. The inclinations of the strata, with the breaks and inequalities, render the globe habitable, by distributing the waters over the surface.

According to geologists, all the substances which now constitute rocks, mountains, and soil, on the surface of the earth, were originally existing in a state of solution in the waters of the 'great chaos.' It is supposed that they, at the beginning surrounded the globe at a great depth. The substances or materials of rocks, thus swimming in the primitive ocean were supposed to fall gradually to the *bottom*, sometimes by chemical, sometimes by mechanical means, and sometimes by both together; and in this manner all the rocks were formed which we now find on digging into the earth. The inequalities of mountains and valleys on the surface of the earth, which were thus produced as soon as the waters began to subside, gradually rose out of the primitive sea, and formed the first dry land. The rocks which were first formed in this manner, are called *Original, or Primary Formation*; because no fossil remains of animals or vegetables, nor any fragments of other rocks were found imbedded in them; hence it was supposed that they were formed before the creation of organized beings. The rocks of this class, are

for the most part extremely hard, and the minerals of which they are composed are frequently more or less perfectly crystallized.

The formation of these rocks, however, did not, it seems exhaust the materials floating in the waters, for the deposition went on, and a class of rocks were formed called *Intermediate or Transition Rocks;* because, on their appearance above the water, the earth was supposed to pass from an uninhabitable to a habitable state, for nearly all the rocks contain organic remains of the lowest class of animals, which are considered as forming the first link of the chain of animated beings. They contain also fragments of rocks of the primary class, and are frequently interposed between those of the primitive and secondary formations, and often partake of the character belonging to both. The rocks of the primary and transition classes are the principal repositories of metallic ores. Rocks of the transition class, however, are not universally interposed between the primitive and secondary ones, for in some instances the transition series are entirely wanting.

After the formation of the primary and transition rocks, it is supposed that the water suddenly rose over them to a great height, covering them in many places, and it again subsided with a new formation called *Lower Secondary Rocks.* They are nearly all distinctly stratified, and contain an abundance of fossil remains of vegetables, analogous to ferns, palms, and reeds; while those of the transition class, contain almost exclusively the remains of marine animals.

After these changes, another most remarkable revolution of the globe took place, and another class was formed called the *Upper Secondary Rocks.* The organic remains of the strata of this

class are chiefly those of marine animals, but of different genera and species from those of the transition class. It is in the rocks of this series that we first meet with remains of animals of a higher class, which possessed a brain and a back bone; they are all of the oviparous order, such as the fish or lizard tribe. This upper series appears to have been formed not only under different circumstances from the lower, but after a long interval, during which the surface of the globe had been much fractured and displaced; for the upper series do not lie regularly upon the other, and parallel with them, but they cover the edges of the lower strata in a confused manner.

Tertiary Strata* comprise all the regular beds which have been deposited subsequently to the chalk strata, on which they frequently repose. It was formerly supposed that tertiary strata were very limited in extent, and were confined to a few districts in Europe; recent observations, however, prove that strata of this class cover considerable portions of the surface in various countries, though there are other countries in which they are entirely wanting. Tertiary strata are the last formed or uppermost of all the regular, rock formations. They consist chiefly of clay, limestone, and friable sand stone; the lower series of these strata contain numerous marine shells, while some of the middle and upper strata contain shells resembling those found in our present rivers, or in fresh-water lakes. The most remarkable fact respecting the tertiary strata is, that some of them contain numerous bones of quadrupeds of the class mammalia, but these for the most part belong to genera and species which no longer exist upon the earth.

* Derived from the Latin, *tertius*, third.

Volcanic and Basaltic Rocks* have been either ejected from volcanoes, or poured out in a state of fusion from rents and openings of the earth's surface. They cover in an irregular manner the rocks of the preceding classes. In some situations the melted mineral matter has taken a columnar form in cooling; in other situations it fills vast fissures, called by miners, *dikes*.

Alluvial or Diluvial† is caused by the wearing down of the rocks, by the action of the weather and other causes, and the washing away of the worn materials by rains and streams of water. Considerable portions of many countries are covered with thick beds of it, which consist of beds of sand or clay, fragments of rock and loose stones, more or less rounded by attrition. In some situations these have evidently been transported from a vast distance, for frequently no rock similar to the fragments occurs within a hundred miles, or more, of the place where they are deposited. They indicate the action of mighty inundations, which have swept over the face of our present continents.

The classes of rocks above enumerated have their appropriate mineral productions, and, with the exception of rocks of the first class, their appropriate organic remains; and it would be as useless to search for regular beds of common coal in the primary rocks, as it would be to search for metallic veins or statuary marble, in the tertiary strata.

The following plate represents a section of the earth between 40° and 45° north latitude. Fig.

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* Derived from the French, *basana*, tawny, alluding to the color of some of the varieties.

† Alluvial is derived from the Latin, *alluvia*, an inundation of water. Diluvial is from the Latin, *diluvium*, the deluge or flood.

1 denotes the primary formation; 2, transition; 3, the lower secondary; 4, the upper secondary; 5, tertiary; and 6, alluvial or diluvial formation.

CHAP. II.

On Rocks.

A rock is a large mass of stony matter, usually compounded of two or more simple minerals, either bedded in the earth or resting on its surface. Sometimes rocks compose the principal part of vast mountains; sometimes huge rocks lie on the surface of the earth, in detached blocks or masses. Under this term, are classed all mineral substances, coal, gypsum, salt, and the like.

The principal rocks are classed and described as follows.

CLASS I.

Rocks denominated Primary.

GRANITE.

Granite* is considered as the foundation rock on which slate rocks and all secondary ones are laid. It sometimes forces its way through the more superficial covering of the globe, and extends to the top of the highest mountains, and is interspersed, in fragments, among all formations which occur above it. It is very abundant and forms enormous beds, or immense mountains, which are traversed by seams or rents in different directions; it is sometimes rudely columnar: in other instances, where the quantity of mica is considerable, granite divides into parallel layers or plates, which have been mistaken for strata. Sometimes it is found in globular masses, which are composed of concentric spherical layers, separated by a granite of a less compact kind, and inclosing a hard or central mass.

Granite is composed of felspar, vitreous quartz, and mica; which are more or less perfectly crystallized, and closely united. Felspar is most commonly the predominating ingredient, and gives to the mass a red, gray, or white color. Quartz generally occurs in small irregular-shaped grains, which have a vitreous lustre. The mica in granite occurs most commonly in small, shining scales, which are most frequently of a black, whitish and silvery, or yellow and gold-like color. It some-

* Derived from the Latin, *granum*, a grain.

times occurs in large hexagonal plates, which is more generally the case in the granite that forms veins in mountains. Mica readily separates or divides into thin, transparent plates, which are sometimes substituted for glass in windows. Beside felspar, quartz, and mica, which were formerly considered essential to all true granite, other substances occupy the place of mica, either in part or entirely. Talc or chlorite, which resembles mica, though softer, sometimes occupies the place of it. In some instances hornblende takes the place of mica, or is intermixed with it. Granite also contains a variety of other mineral substances, but nowise in abundance.

Granite supplies durable materials for architecture; but it varies much in hardness, and care is required in its selection. When taken from a considerable depth in a quarry, it is soft when first raised, and can be easily sawn into blocks, but it soon acquires great hardness by exposure to the air.

The following varieties of granitic rocks are often associated with common granite in the same mountain mass, and may be regarded as contemporaneous with it, being essentially the same rock, accidentally modified by an admixture with other simple minerals.

Common Granite. The felspar white or red, composed of quartz, felspar, and mica.

Porphrytic Granite, in which large crystals of felspar occur in a small-grained granite.

Sienite, or Sienitic Granite,* in which hornblende either wholly, or in part, supplies the place of mica.

Talcy or Chloritic Granite, composed of quartz,

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* Derived from, *Sienna,* in Upper Egypt, where this rock was formerly obtained for architecture.

felspar, and talc or chlorite. Some writers call it *Protogine.*

Felspathic Granite, in which the felspar is the principal ingredient, and the quartz, and particularly the mica, very rare; larger crystals of felspar occur in it. It is frequently nearly white, and is called by Werner, *White Stone*, and by the French, *Eurite.* In its most compact form it becomes a porphyry.

Graphic Granite is composed of masses of crystalline felspar, including dark-gray quartz, arranged in distinct thin plates, which are so bent, as frequently to resemble Hebrew letters. The felspar is sometimes white and at others red.

Orbicular Granite. In this variety, the ingredients of different colors are arranged in concentric zones. Though called granite, this rock is properly a green stone, consisting of white felspar, with spheroidal zones of black hornblende or augite.

Gneiss or Slaty Granite.

Gneiss* is considered as contemporaneous with granite, which frequently passes into it by an almost imperceptible gradation. When the quantity of felspar decreases and the crystals or grains become smaller, if the mica increases in quantity and is arranged in layers, the rock loses the massive structure, and becomes schistose;† we have then the true gneiss. By the reverse of this process, if the quantity of felspar increases, and the mica diminishes the rock loses the schistose structure, and becomes massive; and we have granite

* This word is of Saxon origin, and was applied by German miners to the decomposed stone which forms the walls of their metalliferous veins.

† Derived from the German, *schistus*, slate; which is from the Greek, *schizo*, to split.

again. When the parallel layers of mica are at some distance from each other, they give a striped appearance to the rock. Plates of quartz of considerable thickness sometimes separate the felspar from the mica, and occasionally masses of quartz are imbedded in gneiss. When the mica becomes very abundant, and the other constituent parts are small in size and quantity, gneiss passes into mica slate; gneiss has often a waved form. It is very widely distributed, and abounds in almost every country where granite occurs; and is often interposed between granite and mica slate, or is contained in mica slate, and even in clay slate.

Gneiss, like granite, is a compound of felspar, quartz, and mica; but it contains more mica than granite. It is granular in the small, and slaty in the large; hence it is said to be granular-slaty. The granular felspar and quartz form plates which are separated from each other by the mica. Felspar, although the predominant mineral, is still in less quantity than in granite. The felspar is usually grayish, yellowish, and reddish-white; and sometimes so much altered that it appears earthy. The mica is most commonly gray, which passes through various shades into blackish-gray. The quartz is almost always grayish-white, and generally in smaller grains than the felspar. Besides felspar, quartz, and mica, gneiss contains crystallized limestone, hornblende rock, most of the metallic ores, granite, and crystals of garnet.

There are four varieties of gneiss, namely, that approaching to the granular structure, the waved or undulated, the common which verges on granite, and the thin slaty which passes into mica slate.

Gneiss is used for many purposes, on account of the facility with which it splits into masses of a regular form.

Mica Slate or Micaceous Schistus.

Mica slate is frequently incumbent on gneiss or granite, and covered by common slate; it passes by gradation into both these rocks, the coarser-grained resembling gneiss, and the finer kind, by insensible transition, becoming clay slate. This rock is abundant, but less so than gneiss.

Mica slate is essentially composed of mica and quartz, intimately combined; the felspar, which is a principal constituent part of granite and gneiss, occurs only occasionally in irregular masses of this rock. The color of mica slate is generally a light gray, inclining sometimes to green or yellow; the finer kinds have a pearly lustre; in the coarser kinds the plates are of mica, are more distinct and splendent. The quartz is gray, with its usual vitreous lustre, and is disposed in thin, lenticular masses, interposed between the plates of mica. Sometimes these masses increase in magnitude, and become globular, and then the rock acquires a conglomerated structure. Although the mica forms the principal and predominating ingredient in mica slate, yet it sometimes happens that the quartz is the most abundant, and thus a transition is formed into quartz rock. Mica slate frequently contains imbedded minerals of different kinds. The principal of which are the following: — crystals of garnet, tourmaline, emerald, and schrol. Sometimes it contains beds and plates of crystalline limestone, or is intermixed with serpentine. It also sometimes contains beds and veins of metallic ores.

Mica slate is sometimes split into tabular masses, and employed for many common purposes. When free from garnets and other foreign minerals, it is

extremely difficult to melt, and is used for constructing the hearths and sides of furnaces for melting iron, and the like.

We can distinguish four different varieties, of mica slate, namely.

The *Common* is straight, and rather thick, slaty, and contains garnets and sometimes felspar.

The *Undulated* has a waved structure, and contains neither garnets nor felspar.

The *Talcy* is straight and slaty; contains thick layers of quartz, and the mica has a green color, and inclines to talc.

The *Fine Slaty* borders on clay slate, has a light yellowish-gray color, and contains but a very small portion of quartz; it passes imperceptibly into clay slate.

Subordinate Rocks which occur among Primary.

Argillite or Slate.

Argillite* abounds in most alpine districts, resting either on granite, gneiss, or mica slate, and also occurs in the transition and secondary formations. The primitive slate has a more shining lustre than the other kinds, and partakes more of the crystalline quality of mica slate. As this rock recedes from the primary, its texture is more earthy. Slate rocks are commonly divided into beds of various degrees of thickness, which generally are much elevated, and from the natural divisions of the rock, they often form peaked and serrated mountains. Primitive slate never contains organic remains; for it is among slate rocks of

* Derived from the Latin, *argilla*, white clay. This term may be applied to all kinds of slate which emit the argillaceous or clayey odor.

the transition class, that the fossil remains of animals and vegetables first appear, in every country, which has, as yet, been examined. It is somewhat abundant in all countries.

Slate is a simple mountain rock, having a schistose or slaty structure, with a fine-grained, and dull, cross fracture; it is generally opaque and soft. Its colors are various shades of gray, inclining to blue, green, purple, and red. Oxide of iron is the general coloring ingredient; but in the black varieties it is carbon, which gives the tint of color. The greater number of varieties split easily into slates, which are either plain or variously convoluted. Their surface is sometimes smooth, in other instances, it is traversed by deep grooves; and it is sometimes dull, sometimes shining with a silky or pearly lustre. Independent of the grains of quartz and scales of mica irregularly distributed through it, mica contains large imbedded masses of quartz, and hornblende. Slate is regarded as one of the most metalliferous rocks; nearly all the principal metallic ores have been found in it, either in veins or beds; but it is remarkable that flinty slate seldom contains any repositories of metallic matter.

The following are the principal varieties.

Common or Argillaceous Slate is opaque, and its colors are gray, often more or less shaded with blue, green, yellow, red, or black, also grayish-black, purplish, reddish, and reddish-brown. Its streak is grayish-white, sometimes with a tinge of red.

Roof Slate in its most perfect state is characterized by easily cleaving into large, thin, and straight layers or plates. Its colors are blackish-gray, or bluish-black, bluish, or reddish-brown, and greenish. This slate, when it possesses the

property of cleaving easily, is employed to cover the roofs of buildings. It splits most easily when recently taken from the quarry. When it is of a dark-bluish or grayish-black color, and sufficiently soft, it is employed for writing slates. It is also employed for monuments in grave yards. Some varieties are used for whetstones and grindstones.

Shale, or Slate Clay is opaque, and its colors are gray, bluish, or yellowish-gray, grayish-black, brown, and reddish or greenish. It is much softer than common slate, and is sometimes almost earthy, and is dull, unless rendered glimmering by mica.

Bituminous Shale has a blackish-brown color, and is sometimes grayish. Its fracture is slaty. It is usually very soft, a little unctuous to the touch, and its streak has some lustre. It is impregnated with bitumen, and burns with a flame more or less brilliant. It is generally found connected with beds of coal, and frequently exhibits very distinct impressions of fish and of vegetables, especially of ferns and reeds.

Novaculite, or Honestone* is usually of a greenish-gray, mountain-green, gray, or grayish-yellow color. It sometimes exhibits two colors, as yellow and blackish or brownish, arranged in stripes, and the structure of the yellowish part is usually more compact than that of the other. It is dull or little glimmering. It is employed in the arts under the names of *Hone*, *Oilstone*, *Turkeystone* and *Whetstone.*

Aluminous Slate is of a bluish or grayish-black color, sometimes iron-black, or nearly gray; they are but slightly altered in the streak. Alum may be produced from this slate, hence its name.

Graphic Slate is opaque, and has a grayish or

* Derived from the Latin, *novacula*, a razor or knife.

bluish-black color, which is not altered in the streak. When rubbed on paper or wood it leaves a blackish trace. It is easily cut with a knife; and its surface is smooth, and sometimes even unctuous. It is dull, or has a moderate lustre. It occurs in the vicinity of coal mines, and often accompanies aluminous slate. It is employed by artificers for tracing lines; and when fine, soft, and pure, is used for black crayons in drawing.

Flinty Slate differs from common slate by containing a greater quantity of siliceous earth: and as its name implies, it partakes of the nature of flint. Common slate and flint slate not only pass into each other, but frequently alternate. When the latter ceases to have the slaty structure, it becomes *Hornstone*, or what the French denominate *petrosilex*. If it contains crystals of felspar, it becomes *Hornstone Porphyry*.

Hornblende Rock and Hornblende Slate.

Hornblende* occurs in great abundance in primitive rocks, and also in some rocks of the secondary class. When it forms the principal part of rocks, its color is commonly greenish-black. Massive hornblende in rocks is generally coarsely granular and consists of plates; in hornblende slate, it is frequently radiated or fibrous, and when the fibres are very minute it has a velvet-like lustre. Hornblende slate occurs in beds in granite, gneiss, mica slate, and occasionally in common slate it appears to pass by gradation into serpentine: the change is effected by an increase of magnesia,

* This word is probably derived from the Swedish, *horn*, a corner, and the English word, *blind*. Kirwan says, that the miners, expecting to find some metal in hornblende besides iron, and being disappointed, called it *blind*; in the same way *blende* or *blind* is applied to some other minerals.

which forms one of the constituent parts of hornblende.

Hornblende is a constituent part of many compound or aggregated rocks; it also forms entire beds and masses of great extent and magnitude.

Greenstone and Greenstone Slate.

Greenstone occurs among primitive, transition, and secondary rocks. When in primitive rocks, it occurs in gneiss and mica slate. It frequently alternates with sienite, and is sometimes associated with compact felspar and porphyry. Its structure is often more or less distinctly crystalline, and its ingredients easily distinguishable by the eye. Sometimes also its aspect is almost homogeneous. In transition rocks it is associated with amygdaloid and graywacke. It sometimes occurs in distinct, globular concretions, which are composed of plates. When it occurs in secondary rocks, it is associated with basalt, wacke, and amygdaloid. It often covers wacke and basalt, into both of which it obviously passes. Its structure is sometimes so fine-grained, that the distinct ingredients can scarcely be perceived. Like transition greenstone it may occur in globular concretions. In some instances this rock contains organic remains.

Greenstone Slate usually occurs in primitive rocks. But sometimes it occurs in large beds in transition rocks, and constitutes extensive strata in whole hills. It sometimes contains, also, beds of primitive limestone.

Its structure and fracture are slaty. The hornblende and felspar, which is compact, are nearly in equal proportions. It also contains a small portion of mica and quartz.

When greenstone breaks into prismatic fragments it forms a very useful building stone. Most kinds of greenstone, when heated red hot, plunged into cold water, and pulverized, become a good substitute for puzzolana in preparing water-proof mortar for the construction of wells, cellars, docks, and so forth.

PORPHYRY.*

Geologists have described four formations of porphyry, but it is generally agreed that there is much uncertainty with respect to the situation of these formations. That which occurs imbedded in granite, or which appears to be formed by a change of the structure in that rock, may properly be classed with primary rocks; but is not considered, however, to be an extensive formation. It occurs also in enormous masses covering both primary and transition rocks unconformably; but this porphyry belongs more properly to transition rocks. Porphyry sometimes is a volcanic rock, and appears to form the connecting gradation between granitic rocks, and those of igneous origin. It is somewhat abundant in most countries.

Porphyry is a compound rock, which has a basis in which the other contemporaneous constituent parts are imbedded, either in the form of grains or crystals. Neither the base nor the imbedded parts are always of the same kind. On the differences of the first, depends the distinction of the different kinds of porphyry. The base is sometimes claystone, forming claystone porphyry, hornstone,

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* This word derives its name from the Greek, *porphura*, purple, in allusion to the reddish or purple color, so common to this rock. In the modern acceptation of the term, any rock which is compact or finely granular, and contains distinct imbedded crystals, is called porphyry, whatever may be its color.

forming hornstone porphyry, compact felspar, forming felspathic porphyry, pitchstone, forming pitchstone porphyry; and if it contain much hornblende, it has been named sienitic porphyry. The imbedded parts are most commonly felspar and quartz, which are usually more or less crystallized. The colors of porphyry, or rather its bases, are considerably various; but they very frequently present some shade of red or purple, brown, green, or black.

Porphyry is, in general, susceptible of a good polish, and is manufactured into various articles both for ornament and use. Its hardness is such that it is sometimes formed into mortars and other hard wares.

The following are some of the more common and important varieties.

Felspathic Porphyry has for its base compact felspar. Sometimes, however, the texture of the base is a little foliated, or granular. It occurs in primitive rocks.

Argillaceous or *Claystone Porphyry* has a base of indurated clay, and, has a coarse texture. It occurs in secondary rocks.

Clinkstone Porphyry has a base of clinkstone. It sometimes contains hornblende, quartz, zeolite, and crystalline felspar. It is decidedly of secondary formation.

Obsidian Porphyry has a base of obsidian, and contains crystals of white felspar. It is of volcanic origin.

Pitchstone Porphyry has a base of pitchstone and contains crystals of glassy felspar, or of white, or nearly opaque felspar. It is of volcanic origin.

Green Porphyry contains crystals of greenish-white felspar, imbedded in dark-green compact felspar.

Trap Rock.

The term *trap*,* is usually employed to designate a simple mineral composed of hornblende nearly or quite pure, and also those aggregates in which hornblende predominates. Hence, the presence of hornblende, as a predominating mineral, denotes those minerals, to which most geologists apply the name. These rocks occur in primitive, transition, and secondary mountains. They are some of the most abundant rocks in nature.

In primitive trap, the hornblende occurs nearly or quite pure, or is united chiefly with felspar, forming several varieties of greenstone. But more recent formations of trap, found among transition rocks are corrupted by a ferruginous clay; and in some of the secondary traps, this blackish, indurated clay seems to take the place of hornblende.

Among trap rocks may be enumerated hornblende, hornblende slate, greenstone, greenstone slate, amygdaloid, basalt, wacke, and clinkstone porphyry.

Crystalline or Primary Limestone.

Crystalline limestone, of which statuary marble is a variety, occurs principally forming beds in primary mountains; beds of this mineral occur rarely in granite, more frequently in gneiss, but are most common in mica slate, with which rock it is often much intermixed, and often alternates with it. It is observed that the primary limestone in granite and gneiss, is coarser-grained than that

* Derived from the Swedish, *trappa*, a stair or series of stairs.

in mica slate or common slate. Primary limestone is often much intermixed with serpentine. When beds of primary limestone occur of considerable thickness they sometimes contain beds of metallic ores. No organic remains are found in crystalline limestone in primary mountains. It is found in considerable abundance in some parts of the world, and exists in large beds forming whole mountains.

Crystalline or primary limestone, when pure, is composed of calcareous earth, which scarcely exists as a component part of granite, gneiss, or mica slate; the structure is granular. The white variety known as statuary marble resembles fine loaf sugar, and is imperfectly translucent. Its color is sometimes yellowish, greenish, or inclining to red. From a mixture of mica it has often a slaty fracture and divides into plates. It also contains a considerable quantity of siliceous earth, to which it owes its hardness and durability.

Primary limestone is much used for statues and ornamental architecture.

Serpentine.

Serpentine* occurs chiefly in gneiss and mica slate, in beds, which are frequently so thick as to compose mountain masses of considerable height. It sometimes becomes magnetic, from an intimate intermixture with minute particles of magnetic ironstone. Compound rocks, in which talc and hornblende are predominating ingredients, pass into serpentine. It is common in the mountains in most countries.

Serpentine is to the eye a simple rock generally

* This rock derives its name from its variegated colors and spots, which are supposed to resemble a serpent's skin.

of various shades of light and dark-green, which are intermixed in spots and clouds; some varieties are red. It is proved, however, to be an indefinite earthy compound. It is somewhat harder than limestone. It frequently contains accidental minerals, or is indeterminately mixed with another mineral. The accidentally-mixed minerals are common talc, common asbestos, mica, native magnesia, actinolite diallage, opal, crysoprase, hornstone, amethyst, quartz, and hornblende crystals.

Serpentine is easily cut, and the fineness and closeness of its grain render it susceptible of a fine polish. It is wrought into small boxes and various articles for ornament or use.

It presents two varieties, which sometimes pass into each other.

Precious or Noble Serpentine has its colors uniform; they are generally leek-green or blackish-green, often more or less shaded with yellow. It is always translucent, and the transmitted light has usually a tinge of yellow, even when the reflected light is deep-green.

Common Serpentine presents numerous shades of green, varying from leek-green, greenish-black, or brownish-black to greenish or bluish-gray, with much yellow or brown intermixed; it is sometimes yellow or red. These colors are seldom uniform, but are arranged in stripes, veins, clouds, spots, dots, and so forth. It is opaque, or translucent at the edges.

Diallage, Schiller Spar, or Euphotide.

Diallage* is usually found in masses disseminated in serpentine. It has a foliated structure, and

* Derived from the Greek, *diallage*, difference, alluding to the difference of lustre between its natural joints.

in one direction, is easily divided into plates having smooth, polished faces, sometimes transversed obliquely by cracks or seams. It has been met with in abundance in many countries.

Diallage is seldom, if ever, found in distinct crystals. Its varieties, also, differ very much from each other in some of their external characters. The difference of composition between certain minerals, referred to this stone, is so great, that it is difficult to form an analysis.

Diallage, when cut and polished, presents a beautiful surface, hence it is much esteemed as an ornamental stone.

There are three principal varieties which are as follows.

Granular Diallage has a color of a fine, glass-green or emerald-green. It is opaque, or slightly translucent. It has a shining, foliated fracture in one direction, with a lustre somewhat pearly, or like that of satin. Some specimens have a texture of plates and fibres.

Resplendent Diallage is usually of a deep, bottle-green color, or a metallic-gray, almost silver-white; sometimes also olive-green, brown or blackish. Its plates, sometimes a little curved, have usually a metallic lustre. It sometimes passes into granular diallage.

Metallic Diallage or Bronzite is of a brass or bronze-yellow, or tombac-brown color. Its structure is generally more distinctly foliated, than the preceding variety; and its plates, though less shining, still retain a lustre almost metallic.

Verd Antique.

Verd antique* is a beautiful species of green serpentine composed of serpentine intermixed with crystalline white marble. When polished it has a very brilliant surface, and is highly valued for ornamental sculpture.

Steatite or Soapstone.

Steatite† generally occurs massive, forming veins in serpentine; sometimes it occurs in metalliferous veins in rocks. It is also found in amorphous masses imbedded in basaltic rocks. It is found in considerable quantities in many countries.

Steatite is variable in its composition, the more indurated varieties occur in plates, and appear to pass into soft felspar; the more soft and earthy pass into porcelain clay. It is sometimes mixed with talc, mica, quartz, and asbestos, or is found incrusting other minerals. It is of a milky-white or gray, and is called soapstone from its resemblance in color and feeling to soap. It is sometimes spotted or striped with purple.

Steatite is not susceptible of a good polish; but its softness and tenacity, in consequence of which it may be cut or turned into articles of various forms, and its property of becoming hard by exposure to heat, render it useful in the arts. Hence it may be employed for the hearths of furnaces, the sides of fire places, and stoves. It has also been employed for engraving; for being easily cut, when soft, it may be made to assume any de-

* Verd, signifying green, in French. The word, *antique*, is usually applied to those stones whose quarries are now unknown, or not explored.

† Derived from the Greek, *steatos*, fat, alluding to its unctuous feeling.

sired form, and afterwards rendered hard by exposure to heat. It then becomes susceptible of a polish, and may be variously colored by metallic solutions.

Potstone or Lapis Ollaris.

Potstone* is usually found in connexion with serpentine, and is sometimes mixed with talc and and mica. It is somewhat abundant in some parts of the world.

It is extremely difficult to distinguish this stone from indurated talc, but, in general, it is less distinctly foliated, and is not so brittle. Like most serpentine, it has a greenish color, is translucent, and the lustre is glistening. It is very soft, and feels unctuous, and possesses sufficient tenacity to be turned in a lathe.

This stone may be wrought into vessels of any shape, hence it is used for culinary and other vessels which resist the action of fire.

Quartz Rock.

Quartz† not only occurs as an essential constituent part of granite, gneiss, and mica slate, and disseminated in beds and veins in these rocks, but also in mountain masses and mountains. It is very abundant in almost every part of the world.

Quartz rock, properly so called, is generally of a white or gray color, and often occurs perfectly transparent. It is often intermixed with yellow, orange, red, green, or blue, or black; indeed it

* This stone received its name from having been manufactured into culinary vessels.

† Derived from the Germans.

presents several distinct shades of red, yellow, green, or blue, and sometimes black. It has a granular structure; the concretions vary from the smallest size visible to the naked eye, to that of an orange, or even larger; or it is compact. It frequently contains grains of felspar, and also scales of mica. When the felspar and mica increase in quantity, it passes into granite, or into gneiss, when only the mica, into mica slate. It often contains disseminated iron and copper pyrites.

It is used, especially the sandy variety, in the manufacture of glass; also in the preparation of smalt, and contains enamels. Some of the finer varieties are employed in jewelry.

Topaz Rock.

Topaz rock occurs in primitive formations, generally resting on granite or gneiss and covered by slate. It is of rather rare occurrence.

This rock appears to be composed of fine, granular quartz, prismatic schrol, and gray topaz in grains. These substances are arranged in alternate layers, forming a slaty structure. But the larger masses of this rock are composed of granular distinct concretions. Hence its structure is both slaty and granular. The cavities or fissures of this aggregate are frequently lined with regular crystals of topaz, quartz, and schrol.

Jasper.

Jasper* occurs in certain veins, especially metallic, with transverse primitive rocks, but most generally occurs in thick beds in transition and

* Derived from the Greek, *iaspis*, the name of jasper.

secondary rocks; or even forms whole hills. It sometimes accompanies basalt or greenstone. It is also found in masses of a moderate size in amygdaloid, and there occurs with chalcedony, is disseminated in it, and forms a constituent part of agates; and is sometimes called *Agate Jasper.* It frequently is found in detached or rolled masses in alluvial deposites. It is often transversed by metallic veins, or by veins of quartz. It sometimes contains fossil shells and marine plants. It is of rare occurrence, as a constituent part of beds, or of mountain masses.

Jasper is composed principally of silex, having in combination a quantity of argillaceous matter, more or less mixed with the oxide of iron. Primitive jasper is always opaque. In color it varies from red to green, and frequently consists of alternate stripes of red and green, sometimes perfectly distinct, at others running together.

The high polish, of which jasper is susceptible, the variety and splendor of its colors render it of great value and use in the ornamental arts. It is used for vases, sword handles, and for innumerable purposes in jewelry.

The following varieties deserve notice.

Common Jasper is generally of brown, red, and yellow colors, of different shades, and variously intermixed. It sometimes is found green, bluish, violet, or nearly black, and often gray or white.

Striped Jasper differs from the common kind chiefly in the arrangement of its colors, which are usually some variety of gray, yellow, red, or green; but these colors occur in stripes, veins, rays, circular spots, or in curved concentric zones. That containing round or oval spots is sometimes called *Eyed Jasper.*

Egyptian Jasper is well known by its globular

or spheroidal form, and by the arrangement of its colors. Its colors are brown, yellowish-brown, pale-yellow, or yellowish-gray, always arranged in zones more or less regular, nearly concentric, and sometimes with dots or dendrites of a different color interspersed.

AMYGDALOID.

Amygdaloid* is sometimes found contiguous to greenstone and sienite, or resting on graywacke, or alternating with compact limestone. In such cases it must belong to the transition class or to the latest of the primitive rocks. In other cases, it is associated with wacke, sandstone, and other rocks of recent formation. It is sometimes traversed by veins of quartz and felspar. It is abundant in some countries.

Amygdaloid is a compact rock, composed of a basis, in which are imbedded various simple minerals. The basis of this rock is more or less argillaceous, and may be wacke, fine-grained greenstone, basalt, indurated ferruginous clay, or some other rock belonging to the trap formation. Its color is commonly gray or brown. The imbedded substances are calcareous spar, quartz, chalcedony, agate, epidote, steatite, lithomarge, green earth, zeolite, hornblende, felspar, and other substances.

The following varieties deserve notice.

Toadstone consists of wacke with its cavities filled with calcareous spar, and receives its name from its general aspect resembling the exterior of a toad.

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* Derived from the Latin, *amygdala*, an almond, on account of the oval grains which some varieties contain, resembling almonds in shape.

Basaltic Amygdaloid is basalt with nodules of agate, chalcedony, or calcareous spar.

Variolitic Amygdaloid has a gray, brown, and greenish-gray base of compact felspar, containing small greenish masses, which appear to be epidote. This base is subject to decomposition, leaving the imbedded substance projecting above the surface, and forming a *Variolite.*

GYPSUM OR PLASTER OF PARIS.

Gypsum* or sulphate of lime, is sometimes deposited on the sides of primitive mountains at a considerable elevation; sometimes in valleys; and sometimes constitutes whole hills, or exists in extensive strata at the surface of the earth, or at a great depth below. In short, it is found in primitive, transition, and secondary rocks.

The oldest formation, or *Primitive Gypsum*, is found resting on primitive rocks, and often contained in them. It is often granular, sometimes occurs in plates, usually white, and often much resembling granular limestone. It is sometimes mixed with mica, talc, felspar, and some other substances, but never contains clay, marl, nor organic remains. It sometimes is found between strata of mica slate, or gneiss, and alternating with them, and accompanied by limestone, or hornblende slate.

The next formation, or *Transition Gypsum*, sometimes is associated with graywacke slate, and often covers beds of carbonate of lime, being frequently connected with the fetid limestone.

In most cases, however, gypsum is undoubtedly of secondary or late formation. It occurs at the foot of primitive mountains, or in valleys; and

* Derived from the Greek, *gupsos*, white lime.

sometimes under plains, or forming hills of a moderate size, often at a considerable distance from primitive mountains. Its beds are either horizontal or inclined, and often very thick and not distinctly stratified. It is associated with compact limestone, which is often fetid; also with sandstone, muriate of soda, and generally with clay or marl, with which it usually alternates. This mineral, next to carbonate of lime, is more abundant than any earthy salt.

The texture of gypsum is earthy or granular with coarse grains, and sometimes foliated. It is sometimes white, but often presents various shades of other colors, arising from the presence of oxide of iron. It sometimes contains quartz, borate of magnesia, garnets, arragonite, large masses of sulphur, hornstone, and fragments of compact limestone. *Secondary Gypsum* sometimes contains organic remains; but they are generally more abundant in the beds of marl, which separate those of gypsum. It is sometimes found in efflorescences in volcanic countries.

Gypsum has been employed in many countries as a manure for enriching the soil, and is useful both on sandy and clayey soils. It is sometimes used in sculpture.

CLASS II.

Transition Rocks, conformably arranged.

Graywacke and Graywacke Slate.

Graywacke* is arranged among transition rocks, and is contiguous to porphyry, greenstone, common slate and flinty slate, and is destitute of organic remains. In other cases it alternates with amygdaloid, and nearly or quite compact limestone, and contains organic remains of marine animals, and plants. Sometimes it occurs in beds of gritstone, composed of siliceous earth, or of slate, and associated with the upper transition of mountain limestone. Sometimes it contains fragments, which are evidently the *débris*† of more ancient rocks, that have been broken down by some great catastrophe, and mixed with more recent beds at the period when they were forming. This mode of formation implies that a considerable period elapsed between the formation of the primary and secondary rocks. The fragments are always those of lower rocks, and never of the upper strata. In some situations immense beds of loose conglomerates, composed of large fragments and *bowlders*‡ of the lower rocks, separate the lower rocks from the calcareous formations; such conglomerates may be regarded as occupying the geological place of graywacke, and belonging to the graywacke formation.

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* Derived from the Germans.

† French, signifying fragments.

‡ Round masses of rocks resembling bowls.

Graywacke is composed of angular portions of quartz, felspar, and the fragments of other rocks and minerals, imbedded in a coarse slate, varying in size from two or three inches to the smallest grain, which can be perceived by the eye. The colors are of some shade of gray, or brown. When the imbedded particles become extremely minute, graywacke passes into *Graywacke Slate.* Sometimes graywacke occurs having the same conglomerate structure, and bears the name of *Transition Conglomerate, or Puddingstone.* It is composed of roundish, or angular masses of granite, porphyry, and gneiss, often a foot in diameter, imbedded in common slate, or nearly without a basis or ground.

Transition Limestone.

Transition limestone is one of the most important of transition rocks. It occurs in beds alternating with common slate, graywacke, graywacke slate, and coarse gritstone. Some of these beds are of considerable thickness, and form mountain masses. The lowest beds alternate with slate; they contain few organic remains. Sometimes numerous thin strata of slate and transition limestone, alternate, and are much bent and contorted. It is somewhat abundant in some countries.

The mineral characters of this species of limestone vary considerably, according to the nature of the rocks with which it is associated. It has generally a subcrystalline texture, and is more or less translucent on the edges. From the degree of hardness which it possesses, it will take a good polish. Most of the colored marbles are transition limestone. The prevailing color is bluish-gray, but it is sometimes red, brown, or black; the

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lower beds of this limestone are often beautifully variegated, veined, and spotted. It may be stated generally, that transition limestones are seldom so perfectly crystalline as primary limestone, and they have rarely the compact and earthy texture of secondary limestones. It sometimes contains layers of mica, beds or veins of quartz, pyrites, ironstone, coal, and petrifactions.

Most of the ornamental marbles used in architecture belong to the transition class, while the statuary marbles are of primitive, and the coarser marbles of secondary formation.

Mountain Limestone.

The mountain, or upper transition limestone is, by many geologists, considered as a distinct formation from what they call the true transition limestone; and it is said to be 'separated from it by the important formation of the old red sandstone;' but the latter is only a variety of graywacke, and is acknowledged by those who make it a distinct formation, to graduate into graywacke, and possess all the general characters of that rock, except that it is colored red. It generally occurs in large mountain beds. It is very abundant in many parts of England and in other countries. It contains in some situations beds of imperfect limestone, which may be said to connect the lower transition and mountain limestones in one formation, together with associated beds of graywacke, red sandstone, and gritstone.

The upper transition or mountain limestone is particularly metalliferous; the principal ores are lead, zinc, and copper. Most of the organic remains both in the upper and lower transition rocks, are different from those of the secondary limestones.

Rocks covering Transition Rocks, unconformably

Are porphyry passing into trap or greenstone, and clinkstone passing into basalt. The three former have been described.

Basalt.

Basalt* occurs in beds, veins, and imbedded masses of transition limestone. The dykes intersect both primary and secondary rocks, but they everywhere present indications of their action on the adjacent rocks. Sometimes it intersects a rock composed of gneiss, when the basalt becomes nearly compact, and approaches to the character of hornstone; and the gneiss has a red and burnt appearance, approaching in its nature to porphyry. It is abundant in some countries.

Basalt has a greenish or brownish-black color, is difficult to break, and possesses a considerable degree of hardness; it will, however, yield to the point of a knife. On examination with a lens, even the more compact varieties of basalt are seen to be composed of minute crystalline grains; it frequently contains yellowish grains of a mineral called *Olivine;* it contains also grains of iron sand, and a considerable portion of the black oxide of iron. Basalt is fusible into a black glass, and is magnetic. The iron which it contains, passes into a further state of oxygenation when exposed to the air. Hence basaltic rocks are generally covered with a reddish-brown incrustation. Very black basalts are chiefly composed of augite. Soft earthy basalt, intermixed with green earth, forms

* Derived from the French, *basané*, tawny; the color of some varieties.

the rock called *Wacke*. When basalt or wacke contains rounded cavities, filled with zeolites, chalcedony, or calcareous spar, they form *Amygdaloid*. Basalt occurs in distinct concretions of various descriptions. They are generally columnar, varying from a few inches to some fathoms, even to upwards of 100 feet in length; the number of sides varies from three to nine, and of these, the nine-sided are the most rare; they are straight, curved, and either parallel or diverging; sometimes they are articulated, and the joints have concave and convex faces. Sometimes these concretions are collected in large groups, and many of these groups or colossal concretions, form a hill or mountain. Sometimes they occur in tabular, sometimes in globular concretions; these latter are frequently composed of concentric lamellar, or of columnar concretions, radiating from a centre. Some varieties are composed of large, coarse, and fine granular concretions. The most frequent imbedded minerals are olivine and augite; besides these, grains and crystals of felspar, and also of hornblende, calcareous spar, and magnetic iron ore, are met with.

When calcined and pulverized, basalt may be employed as an ingredient in water-proof mortar. It is sometimes used as a touchstone for metals; or is employed in the manufacture of green-glass bottles.

CLASS III.

Rocks denominated Secondary.

Lower Series.

The lower series of secondary rocks are almost all distinctly stratified; they consist chiefly of sandstone, soft argillaceous slate, called shale or slate clay, of beds of coal and ironstone.

Sandstone.

Sandstone, although most decidedly a secondary rock, has been formed at different periods, under different circumstances, and is hence associated with different rocks. It often alternates with limestone, and forms hills of considerable magnitude. It is sometimes found resting on graywacke, or even on primitive rocks, or is connected with coal. This kind is very coarse, and of a reddish color. Another kind which is variegated, and appears to be of a later deposit than the preceding, sometimes occurs resting on gypsum, and is at the same time covered by shell limestone. Other formations of sandstone are more recent, and are found covering gypsum. Various organic remains are found in sandstone, such as reeds, impressions of leaves, trunks of trees, and both marine and fresh-water shells. A distinct stratum called *Old Red Sandstone*, and another called *Millstone Grit*, have been given by most geologists. But modern geologists reject them. The old red sandstone is a graywacke colored red by the accidental admixture of oxide of iron. It occupies the

geological position of graywacke and graywacke slate, into which it passes merely by a change of color. The millstone grit is a kind of graywacke, which has a coarser grit than sandstone. Sandstone is abundant in most countries.

Sandstone, is in most cases composed chiefly of grains of quartz, united by a cement, which is never very abundant, and often, indeed, is nearly or quite invisible. These grains are sometimes scarcely distinguishable by the naked eye, and sometimes their magnitude exceeds an inch in diameter, as in those coarse sandstones, called *Conglomerate*, and sometimes *Puddingstone or Breccia.* Its most common color is gray or grayish-white, sometimes with a shade of yellow, brown, or green, and sometimes it is reddish or reddish-brown. In some cases the stone is uniform in color, in others it is variegated.

Sandstone is much employed in the useful arts. That variety by the name of *Freestone*, when sufficiently compact, is used for building houses. Some varieties are wrought into millstones for grinding corn, or for wearing down other minerals, preparatory to a polish. When the texture is sufficiently porous it is used for filtering water. Some varieties are employed for whetstones.

The following are some of the varieties.

Red Sandstone or Freestone is of a dark-reddish or reddish-brown color and is composed of coarse grains, united by an argillaceous cement. It sometimes contains scales of mica, or embraces petrified wood.

Variegated Sandstone presents a diversity of colors, as yellow, green, red, brown, and white, which are commonly arranged in stripes, or zones, either straight or curved. It has usually a compact texture and a fine grain. It frequently con-

tains oval or globular masses of clay, called *Stone Galls or Clay Balls.* Sometimes this stone contains oolites. Its cement is usually argillaceous.

White Sandstone is of a whitish-gray, or gray color, and is generally uniform; but it is accidentally marked with yellowish, reddish, and brownish spots. It is sometimes solid and firm, and sometimes very brittle. Its cement is often calcareous. This includes many of the more common varieties of sandstone used in the arts.

Flexible Sandstone has a slaty texture, is flexible, though it is brittle, but not elastic. If a plate of this stone be held horizontally, it bends by its own weight. Its flexibility is imputed to the presence of flat, elongated grains of quartz, which much resemble plates of mica.

Siliceous or Quartzy Sandstone has a very fine, close texture, and a conchoidal fracture with some lustre. Its granular structure, however, is perceptible in consequence of its translucency. It much resembles some varieties of quartz. The color of siliceous sandstone is generally either red, or light-gray, and is sometimes variegated.

COAL.

Coal is found in each of the five lower formations, and occurs sometimes in irregular masses and rarely in veins; but most frequently in beds, having a variety of inclinations and windings. Sometimes the same bed so changes its direction, as to form an acute angle with itself. The natural associations of coal with other minerals are remarkably uniform, and in general well determined. The great coal formation appears to be confined to the lower secondary strata, generally resting on transition limestone. In some situations, the un-

der transition rocks are wanting, and the series of coal rests on granite, with the intervention of a thick bed of conglomerate. No mineral coal, both good in quality and abundant in quantity, has ever been found either in the primary or in the lower transition rocks, or in the upper secondary or the tertiary strata.

A variety of opinions have been formed respecting the origin of coal. In the primary and transition mountains, a particular species of coal occurs in small quantities which is extremely hard and splendent, and burns without smoke or flame, and is called by mineralogists *Anthracite*, and it clearly resembles, and appears to pass into the mineral called plumbago, or graphite. Plumbago and anthracite are so completely mineralized as to present no external indications of a vegetable origin; but the strata over common coal abound in vegetable impressions, and the cortical part of the vegetable is frequently seen converted into mineral coal. It is not often that vegetable impressions are found in the coal itself, but some regular coal beds are composed of distinct layers of vegetables converted into true mineral coal; but when separated, preserving the distinct cortical impressions of plants throughout the whole thickness of the coal; and it is reasonable to believe, that all such coal beds are formed of similar plants, though the vegetable impressions may be effaced. Wood coal, or brown coal, is found in low situations, and appears to have been formed of heaps of trees buried by inundations under beds of clay, sand, or gravel. The woody part has probably undergone a certain degree of vegetable fermentation, under the pressure of the incumbent earthy matter, by which they have been carbonized and consolidated. In some specimens of this coal, the vegetable

fibre or grain is perceptible in one part, and the other part is reduced to coal. In black or common coal, the vegetable extract and resin are destroyed, and the charcoal and bitumen alone remain; but wood coal and common coal bear in other respects too close a resemblance, to allow us to ascribe to them a different origin, though they were probably formed from different tribes in the vegetable kingdom, and under different circumstances.

In wood coal we may almost seize nature in the act of making coal, before the process is completed. These formations of coal, are of far more recent date than that of common coal, but their origin must be referred to a former condition of the globe, when the vegetable productions of tropical climates flourished in northern latitudes. The vegetable origin of common mineral coal appears to be established by its association with strata, abounding in vegetable impressions, by its close similarity to wood coal, (which is undoubtedly a vegetable product,) and lastly, by the decisive fact, that some mineral coal is entirely composed of layers of mineralized plants.

But though the vegetable origin of mineral coal may be satisfactorily established, there is considerable difficulty in conceiving by what process so many beds and seams of coal have been regularly arranged over each other in the same place, and separated by strata of sandstone, shale, and indurated clay.

It has been supposed that coal strata were deposited on the bed of the ocean; but this is not probable, for many of the vegetable species whose remains are found in these strata, are of marsh plants; and some of the species of ferns are land plants, and probably grew on dry land surrounding the coal basins when they were lakes. If we sup-

pose that these lakes were periodically dry land, and again filled by sudden inundations, we shall have the conditions required for the succession of carbonaceous and earthy strata which take place in a coal field; a repetition of such inundations would fill up the lake or basin. Nor can such a supposition appear improbable; for as the species of plants whose remains are found in the coal strata are analogous to those of warm climates, we may infer, that in a former condition of the globe, these northern latitudes had the temperature of tropical regions, and also the hot and rainy seasons which promote the rapid growth of vegetation, and occasion periodical inundations.

To convert wood coal, or jet into true coal, some further process than long submersion in water seems necessary. The latter substance, yet jet, was reduced to powder, by Dr. M'Cullock, and put into a gun barrel and covered close with Stourbridge clay; it was then exposed to moderate red heat. By this process it was converted into a substance having all the external characters and chemical properties of true mineral coal; and the clay was converted into coal shale. But though in the laboratory of the chemist, the last stage of the formation of coal requires artificial fire, yet in the great laboratory of Nature, vegetable fermentation and compression, may evolve sufficient heat for the ultimate formation of mineral coal. It may however deserve notice, that most great repositories of coal are intersected by beds and dykes of basalt, which is now admitted to be of igneous origin.

Pressure and time alone may be sufficient to produce the destruction of vegetable organization, and the perfect consolidation of beds of coal, as is proved by a complete consolidation of loose materials left in coal mines, when the supports are remov-

ed and the upper strata sink down. In a few years, scarcely a trace of former operations remains. In contemplating natural causes, we are too apt to measure their power by the results of artificial processes, and by observations continued for a short portion of human life. The substances found in the neglected vessels of the chemist, often prove to us that changes in the physical properties of bodies are effected by time, which it would be difficult to imitate in common experiments.

Coal is essentially composed of carbon and bitumen in variable proportions; the carbon however predominates and often constitutes nearly three-fourths or the whole. Small portions of oxide of iron, silex, and alumine are also present. Its color is brown or black, which varies a little in its shade, but is almost always shining; its surface is sometimes very beautifully irised with lively colors. It occurs in opaque masses, the texture of which is slaty or compact, and the fracture generally even or conchoidal.

The uses of coal are numerous and important; but vary much according to the quality of the coal. For those purposes of the forge, which require a hollow fire, the slaty coal must be employed, as this variety possesses the property of agglutinizing, and thus produces over the iron a kind of arch, which concentrates the heat. But the same property of caking, which depends on its bitumen, renders it unfit for many operations in the arts. In these cases, it must previously be deprived of its bitumen and sulphur, and thus converted into coke.* Coal has been used with success in bak-

* Coke is light, spongy, and of a shining, steel-gray color. It burns less easily than coal, but produces a great heat, and does not cake nor smoke. It is prepared by exposing coal to heat, but prevented from burning, by the exclusion of the air, in a similar manner as charcoal is prepared from wood. By this process it is deprived of its volatile products, consisting of bitumen, or *coal tar*, and ammonia.

ing stone ware. It has of late years been successfully applied to the production of inflammable gas, for the purposes of illumination.

When coal contains any considerable quantity of pyrites, it is rendered more or less unfit for use, in consequence of the sulphurous acid, produced during its combustion. Sometimes also the heat, liberated by the decomposition of the pyrites, is sufficient to inflame the coal; and hence the spontaneous combustion of many coal mines, called by miners the *fire damp*.

Numerous varieties of coal exist, deriving distinctions partly from their state of aggregation, but principally from the proportions of their bitumen and carbon. Excepting the anthracite they may be treated under the two divisions of *Black Coal*, and *Brown Coal*.

Brown Coal.

The color of this coal varies from brown to brownish-black; it occurs massive, with a vegetable structure; the cross fracture is imperfectly conchoidal. It yields readily to the knife, and burns with a disagreeable odor. Some varieties are soft from decomposition, others contain much earthy matter and pyrites. This coal occurs in low situations, and in alluvial soil, and is evidently formed by the bituminization of wood or vegetable matter.

The following are the principal varieties.

Bituminous Wood Coal presents a ligneous texture, and very seldom has anything like conchoidal fracture, and is without lustre.

Earthy Coal consists of loose, friable particles.

Moor Coal is distinguished by the want of ligneous structure, by the property of bursting and splitting into angular fragments, when removed from its original repository, and the low degree of lustre upon its imperfect conchoidal fracture.

Common Brown Coal, which, though it still shows traces of ligneous texture, is of a more firm consistency than the rest of the varieties, and possesses higher degrees of lustre upon its more perfect conchoidal fracture.

Black Coal.

This well-known mineral has a black color, a shining or glistening lustre, inclining to resinous; it has a stratified or thick, slaty structure; the cross fracture varies in different varieties, passing from uneven to even and conchoidal; it is brittle and easily broken. Some of its varieties immediately join those of brown coal. Sometimes they are joined by numerous transitions, so that it often becomes doubtful to which of them we should ascribe certain specimens, though they undoubtedly are members of this species. As its varieties consist of variable proportions of bitumen and carbon, they, of course, must vary in their inflammability.

The following are the principal varieties.

Pitch Coal is of a velvet-black color, generally inclining to brown, having a strong lustre, and presenting, in every direction, a large and perfect conchoidal fracture.

Hard or Slate Coal is of a black color, either pure, or with a slight tinge of gray or brown. Its structure is slaty or foliated, and its layers usually divide into prismatic solids, with bases slightly rhomboidal. Its cross fracture is even or a little conchoidal, and sometimes uneven; its lustre is

resinous, frequently more or less shining, and on the foliated fracture it is splendent. It burns easily with a white flame, and swells and agglutinates, or cakes, and leaves but little residue.

Foliated Coal resembles the slate coal, only its plates are thinner.

Coarse Coal is a little harder and heavier than slate coal. Its color is dark, grayish-black, and its lustre glistening. Its structure is usually somewhat slaty, but its fracture is coarse-grained and uneven. It burns less readily than the slate coal, and does not like that, swell and agglutinate; it also leaves a more abundant residue.

*Cannel or Candle Coal** is of a black color, having usually a slight tinge of gray. Its texture is compact, and its fracture even or conchoidal with large cavities; its lustre is resinous and glistening. It is sufficiently solid and hard to be cut and polished, and is the least brittle variety of vegetable coal. It burns without softening, with a large, bright flame of short duration, leaving a sutty substance. It does not produce great heat. Its odor is not unpleasant. It is sometimes employed for making toys.

Soft or Caking Coal often alternates with common coal. It possesses the caking property, and can be burned for coke with advantage.

Anthracite Coal.

Anthracite† is the name of one of the most valuable kinds of coal used in the arts and domestic economy. It is of a grayish-black, or iron-black color, with a lustre imperfectly metallic; it is

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* Derived from the circumstance of its burning like candles, which, in Lancastershire, are called *cannels*.

† Derived from the Greek, *anthrax*, a coal.

opaque and has a conchoidal fracture. Some varieties abound in fissures, in consequence of which they possess an irregular, columnar structure, and a lower degree of lustre; while others are highly compact, of a black color, with a shining lustre, and occasionly highly tarnished with iridescent colors. This coal consists wholly of carbon, mixed with a slight and variable proportion of oxide of iron, silex, and alumine. It is inflammable with some difficulty, and burns without smell or smoke, leaving a more or less earthy residue. It is less widely distributed than the bituminous coal, and belongs almost exclusively to transition rocks; but it is sometimes found in the lower series of the secondary class.

The following are its most prominent varieties.

Slaty Anthracite is the most common kind. Its structure and fracture are of the same direction, and are more or less slaty; and it commonly divides into layers, the surface of which is uneven or undulated, and sometimes furrowed. Its cross fracture is more or less conchoidal.

Granular Anthracite occurs in granular masses which are friable, and strongly soil the fingers.

Conchoidal Anthracite has a compact texture, and, as its name imports, has a conchoidal fracture, often with a very high, metallic lustre. It often breaks into large scales or fragments with undulated or uneven surfaces. It sometimes scarcely soils the fingers.

Columnar Anthracite occurs in masses, composed of thick, columnar concretions parallel, but a little curved. It is very frangible, has an imperfectly conchoidal fracture, and burns without flame or odor, leaving a residue of whitish ashes.

IRONSTONE.

Ironstone occurs abundantly in thin, regular strata, which alternate with shale, sandstone, and coal.

This stone is composed principally of iron combined with oxygen, corbonic acid, and water, and a small quantity of silex, and in some instances with calcareous earth. If it be of good quality, it yields more than thirty per cent. of iron. In some of the beds of clay over coal, detached nodules of ironstone occur, which are smelted into iron. Ironstone has an ash-gray, yellowish-gray, and dark, bluish-gray color; and sometimes brown or reddish-brown; the colors darken by exposure to the air. It is dull, and has an earthy appearance and texture; the fracture is even or flat-conchoidal. The structure sometimes inclines to slaty. Ironstone occurs massive, and in kidney-shaped nodules, and impressed with the form of plants, and more rarely of bivalve shells. Ironstone does not affect the magnetic needle, but it becomes black and highly magnetic before the blowpipe.

From this stone iron is obtained, the uses of which are well known.

The following are the principal varieties.

Nodular Ironstone often occurs in the soft argillaceous strata which accompany ironstone; it is generally more productive of iron than the stratified ore. *Ætites*, or hollow nodular ironstone, occurs frequently in alluvial soil; the nodules are composed of concentric layers, and often contain a loose, rounded nucleus; sometimes the cavity is filled with friable yellow earth.

Columnar Clay Ironstone occurs in amorphous

masses and in rounded pieces, which are composed of prismatic concretions laterally aggregated, and more or less adhesive. It is earthy and brittle; sometimes the interstices between the prisms are lined with galena, blende, or calcareous spar.

Pisiform Ironstone consists of spherical grains of the size of a pea. The globules are composed of concentric layers, and are generally united by a ferruginous cement. The colors are reddish, or reddish or yellowish-brown; it is soft and earthy internally.

Lenticular Ironstone occurs in small granular or lenticular concretions aggregated in masses; the color is reddish or yellowish-brown, and the lustre pseudo-metallic.

Jasper Ironstone appears to be formed by a combination or admixture of iron and siliceous earth; it has a reddish or yellowish-brown color; it occurs massive; the fracture is flat-conchoidal, passing into even; it yields to the knife, is brittle, and is easily broken.

CLASS IV.

Upper Secondary Rocks.

The upper secondary rocks comprise all the different formations above the great regular coal formation. The general mineral characters of this formation may be briefly described; they are principally calcareous, though siliceous sandstone; and thick beds of sand and clay form part of the series. Rock salt and gypsum are the most valuable minerals found in this formation, and it is from them that all the important salt springs issue. Some of the rocks of this class yield useful mate-

rials for architecture, but the stone is too generally soft and perishable. To the rocks of this class, Werner gave the name of *Flœtz or Flat Rocks*, because in the northern parts of Europe they are generally arranged nearly in horizontal strata; but this character is altogether inapplicable to the upper strata in other countries. The principal rocks of this class are as follows: magnesian limestone, red marl and sandstone, lias limestone, oolite with subordinate beds of clay, sand, sandstone and clay, chalk, lignite or wood coal, gypsum, and rock salt.

Magnesian Limestone or Dolomite.

The geological position of this rock is immediately over the great coal formation, which it covers unconformably, and under the red marble and sandstone. When the magnesian limestone is absent, the red marble occupies its place. Some geologists regard the magnesian limestone as an accidental formation in red marle. It not only forms extensive strata in rocks of considerable magnitude, but it occurs in various situations in strata, alternating with common limestone.

Magnesian limestone does not possess any well-marked, invariable, physical characters which distinguish it from common limestone; it is by chemical tests only that we can certainly ascertain the presence of magnesia, the proportion of which is sometimes equal to that of the lime; more frequently it forms about two-fifths of the mass, and in chalk, it rarely exists in a greater proportion than one-tenth. The magnesian limestones in alpine districts, and in upper stratified rocks, differ from each other in the same manner as the common limestone, in the different situations.

Magnesian limestone is employed in the manufacture of mineral waters. Carbonic acid gas, and sulphuric acid are obtained from it.

Magnesian limestone may be arranged in the following divisions.

Crystallized Dolomite.*

The principal varieties of crystallized dolomite are as follows.

Dolomite Spar, Rhomb Spar, or Bitter Spar occurs amorphous, and in rhomboidal crystals, like calcareous spar, and which have a similar cleavage, parallel to the faces of the rhomb. It occurs in compact dolomite and imbedded in chlorite slate, and is found in various other rocks in beds. With the exception of hardness and specific gravity, its other characters resemble those of calcareous spar. Dolomite spar occurs sometimes in prismatic concretions.

Miemite is a green, or greenish-white variety of dolomite spar, found imbedded in gypsum.

Brown Spar, or Pearl Spar is distinguished by its pearly lustre, which is of different degrees of intensity, from shining to glimmering; its colors are white, or pearl-gray, but sometimes reddish or brown; by exposure to the atmosphere it becomes brown and almost black, on which account it was called *Brown Spar*; it it more or less translucent. It occurs in small crystals and amorphous; the crystals are rhombs, but are frequently curved or lenticular and densely aggregated, and often cover the surface of other crystals. It occurs also in globular, lamellar, or reniform masses, and is sometimes fibrous. It often contains so large a

* Dolomite is derived from *Dolomieu*, who first noticed it.

portion of iron and magnesia as to make it uncertain whether it should not be classed with sparry iron ore.

Massive Dolomite.

This species resembles fine granular limestone, or common statuary marble ; it forms beds of vast size in many alpine districts. It colors are generally white or grayish-white. The structure is finely granular, the grains, generally more or less adhering than in statuary marble, and are easily separated by the finger; but some varieties possess greater hardness.

There is a variety of dolomite which is flexible when cut into long slabs. It is often intermixed with tremolite and talc ; it frequently contains grains of yellow pyrites of iron, arranged in thin seams.

Common Magnesian Limestone.

This species has no well-marked physical characters which will invariably distinguish all the varieties from common limestone. It has frequently a reddish-brown color, and more or less of a sparry or crystalline structure, and is generally harder than common limestone ; but some varieties are a light, yellowish-gray, and are compact or earthy. Some varieties, on being struck with a hammer, emit a fetid odor.

Magnesian limestone, when burned, retains its causticity longer than common limestone, and is hence more efficacious in agriculture, when employed to decompose roots, or vegetable matter on land recently brought under cultivation.

Red Marle and Sandstone.

No formation presents such a great variety of mineral characters as the red marle and sandstone, and geologists have frequently been greatly perplexed in their attempts to arrange and class the beds which occur in this formation. The composition of different strata is extremely various. In some parts we find an argillaceous marle in different states of induration; in other parts we meet with regular strata of siliceous sandstone; and sometimes there is a conglomerate sandstone, or soft sandstone, inclosing rounded pebbles of quartz and lydianstone. In the lower part of this formation, the beds are porphyritic, and contain imperfect crystals of felspar; sometimes they pass into amygdaloid and trap. The fine siliceous sandstones, when closely examined, are often found to contain fragments of neighboring rocks.

The beds of this formation have generally the red color which the name implies, but are often marked with irregular veins and spots, of a yellowish or bluish color, and the sandstone is sometimes gray, with occasional spots of red. Red marle produces some of the most fertile soils known, which may be partly owing to its formation from soft trap rocks. Some basaltic rocks decompose rapidly, and are known to form soil favorable to vegetation. The most valuable substances found in red marle are gypsum and rock salt.

When the red marle formation is fully developed, it may be arranged under three divisions: the *lower*, which consists of fragments of different rocks cemented by sand or marle, and of beds of imperfect porphyry; the *middle* beds, consisting

chiefly of sandstone; and the *upper*, consisting of marle and variegated sandstone, in which, beds of gypsum and rock salt occur.

Rock Salt, and Common Salt.

Rock salt and salt springs most generally occur at the feet of extensive mountain ranges, which adds probably to the opinion, that these ranges were once the boundaries of extensive lakes of salt water. Beds of rock salt commonly occur in red marle, and are almost always accompanied by beds of gypsum. Rock salt and gypsum, however, do not always occur in red marle, but between calcareous beds, similar to the lias limestone. Sometimes salt lakes occur, which rest on beds of rock salt. These lakes, when dried up in summer, leave immense masses of salt at the bottom.*

The most natural hypothesis respecting the formation of rock salt, at least in some situations, is that caused by the gradual evaporation of lakes and pools of salt water, which remained when the ocean retired from the present continents. This mineral, by slow evaporation would be separated from the impure salts which exist in sea water; and as these salts are more deliquescent than rock salt, they might be washed away, before the beds of rock salt were covered with earthy strata.

The uses of this salt, though numerous and important, are too well known to require any particular notice.

* The waters of the sea contain about 2.5 per cent. of salt. According to La Place, the average depth of the ocean is ten miles; were the water evaporated, the salt would form a bed 7000 feet in thickness, a mass equal to cover all the present dry land to the depth of 2000 feet. And as the ocean has once covered the present continents, we need not be surprised at the quantity of rock salt found in various parts of the globe.

Transparent, colorless rock salt consists of muriate of soda, nearly in the highest state of purity; or, according to Sir H. Davy, of chlorine and sodium. It has so little water of crystallization, that it scarcely decrepitates when thrown on burning coals, in which it differs from salt prepared artificially by evaporation. The colors of this well-known salt are generally white, gray, or red; it sometimes occurs of various colors, as blue and green; the blue varieties are clouded. The deep-red color is derived from the oxide of iron. Rock salt varies from transparent and translucent to opaque; the lustre is shining and vitreous; it occurs massive, stalactical, and crystallized, in cubes, in cubo-octahedrons, and octahedrons. The structure is distinctly laminar; it breaks easily into cubic fragments, the cube being the primitive form.

Lias Limestone and Lias Clay.

The regular stratified lias* limestone occupies the lower part of a bed, which rests upon red marle, and the lias clay occupies the upper part. The lower beds of the limestone have often a yellowish-white color, and are called *White Lias*. The blue lias limestone has generally a dark, smoky-gray color, a dull, earthy texture, and an imperfectly conchoidal fracture. The purest beds contain from eighty to ninety per cent. of carbonate of lime, combined with bitumen, alumin, and iron. If iron enter largely into the composition of this limestone, it forms a lime, which, when burned, has the property of setting under water.

* *Lias* is a corruption of the word, *layers*, and is applied to some strata which are generally very regular and flat, and rise in thin slabs or layers when taken from the quarries.

The finer kinds of white lias will receive a polish, and may be used for lithography.

Lias Clay frequently occurs in the form of soft slate, or shale, which divides into very thin plates. The shale is often much impregnated with bitumen and with iron pyrites, and will continue to burn slowly when laid in heaps of faggots, and once ignited. During this slow combustion, in the pyrites, it is decomposed, and combines with the oxygen of the atmosphere and with a portion of the alumin in the shale, and forms sulphate of alumin or alum. The composition of lias clay is nearly the same as lias limestone. It is impregnated with a considerable portion of muriate of soda, and sulphate of magnesia, and soda.

The beds of lias limestone and lias clay are particularly distinguished by the number and variety of the organic remains which they contain. The most remarkable of these are certain species of fish, and those of vertebrated animals, allied to the order of lizards. The fossil fish are generally found in the middle of flattened balls of limestone, in which the form of the body and scales is often well preserved.

Oolite or Roestone.

Oolite* or roestone consists of globules almost always united by a calcareous cement; and the beds or masses, thus formed, generally occur immediately above the lias strata; sometimes also with compact limestone, or even with gypsum. It always is found in globular or spheroidal masses, usually very small, but varying from the size of a poppy seed to that of a pea. Hence it is some-

* Oolite is derived from the Greek, *oon*, an egg, and *lithos*, stone; from its resemblance to the roes of fish; and was once considered as roes of fish petrified.

times called *Peastone*. These globules appear to be composed of a compact, calcareous nucleus, invested by concentric layers, variable in thickness. These layers, often perceived with difficulty, have in most cases a compact texture. The nucleus is sometimes detached, leaving its place empty.

Oolite has a dull fracture, which appears to be splintery. It is nearly or quite opaque, and has a brown, reddish-brown, or yellowish-gray color. It abounds with organic remains.

Some varieties of oolite have been much used in architecture; but it is not durable.

Chalk.

Chalk is never found associated with primitive earths. It may rise into hills of considerable height, or appear many yards below the surface of a level country. It occurs in thick beds, seldom distinctly stratified, in most cases nearly or quite horizontal, but sometimes highly inclined or nearly vertical. The upper beds contain numerous nodules and short, irregular veins of flints; the lower chalk contains fewer flints, and is generally hard; below this, there occur beds of soft chalk, called *Chalk Marle.* The French divide the chalk formation into the *lower* or chalk marle, with green particles; the *middle* or coarse chalk, which is of a grayish color and intermixed with sand; and the *upper* or white chalk, which contains nodules of common flint chalk, which sometimes contains organic remains, but neither coal, nor any metallic substance, except the sulphuret or oxide of iron, which has been found in it. Chalk is abundant in many countries.

Chalk always occurs amorphous, with a dull, earthy fracture. Its prevailing color is white, but some of the lower beds incline to gray or brown; it is opaque and has an earthy texture, and is generally so soft as to yield to the nail, though some of the lower beds are sufficiently hard to be employed for buildingstone. It is very nearly a pure carbonate of lime, containing minute quantities of alumin and oxide of iron. It appears to have been deposited from a state of suspension, rather than solution in water. It sometimes contains a notable portion of magnesia, and may then generally be known by an appearance of dendritical, spotted delineations on the surface of the natural parting, and by minute, black spots, like grains of gunpowder, in the substance of the chalk.

Lignite.

Lignite* appears in three distinct formations, namely, upper secondary, tertiary, and alluvial. Lignites which are manifestly bituminized wood, hold an intermediate place in the gradation between vegetable matter and bituminous coal. They have the fibre of the former, with the jetty lustre and fracture of the latter. Some varieties closely resemble peats in their chemical characters, others seem to graduate into perfect coal. It is therefore the geological position which defines this combustible. Whatever is found in the strata above the magnesian limestone has been called a *Lignite*. It occurs abundantly in oolite, passing into coal. In some of its lowest deposits, regular beds are formed, sometimes of considerable thickness; and where these alternate with shales,

* Derived from the Latin, *lignum*, wood.

sandstones, and limestones of the series, the superficial aspect is so much like that of regular coal, that it is sometimes mistaken for that deposite. Beds of lignite very frequently contain fossil remains of animals and vegetables.

Lignite is sometimes employed for fuel where a great heat is not requisite. Some of its harder varieties, particularly jet, are frequently cut and polished for ornamental purposes.

Most of the varieties of lignite burn with flame, but do not swell nor cake, like coal; the odor which they exhale, is also sensibly different from that of burning coal or bitumen, and is usually unpleasant, sometimes sharp, or fetid. They leave a residue of ashes, like wood, but more abundant. Their color is sometimes black, but more frequently brown.

The principal varieties are as follows.

Jet is of a pure and deep-black color, sometimes with a tinge of brown. It occurs in opaque, compact masses, so hard and solid, that they are capable of being turned in a lathe and highly polished. Its fracture is conchoidal or undulated, shining or even splendent, and has a resinous lustre. It sometimes presents a dendrited texture.

Brittle Lignite may be distinguished from jet, which it resembles, by its extreme brittleness. Its surface is always cracked, and is very easily divisible into cubical fragments. Its color is black or a shade of brown, and less shining than that of jet. Its longitudinal fracture is sometimes of a ligneous texture; its cross fracture is even, or a little conchoidal, with a moderate lustre. It falls to pieces on exposure to the air.

Bituminous Wood has the form of the roots, branches, or trunks of trees somewhat compressed; and its texture is perfectly ligneous. Its color is

generally light or dark-brown, but sometimes it is nearly brownish-black, or with a shade of blue or red. It is opaque, more brittle than wood, has a shining streak, and is very light. The longitudinal fracture is fibrous, with but little lustre; the cross fracture has more lustre, is sometimes a little conchoidal, and often shows the concentric, annual rings of the wood. When sufficiently abundant it is employed for fuel.

Brown Lignite, in many respects, resembles bituminous wood. Its general structure is often a little slaty; its cross fracture is even or conchoidal with a resinous lustre somewhat shining.

Earthy Lignite is of a black or blackish-brown color, or a lighter brown, and sometimes with a tinge of red. It is often perfectly friable and has but little solidity. Its fracture is dull, fine-grained, earthy, but sometimes has a ligneous texture.

Aluminous Earth differs but a very little from earthy lignite. It has usually a sharp taste. By lixiviation it affords alum.

CLASS V.

Tertiary Formations.

The tertiary formations comprise all the various regular beds of limestone, gypsum, lignite, clay, marle, sandstone, or sand, which have been deposited after chalk. The most remarkable fact respecting the tertiary formations is, that many of them contain the bones of mammiferous quadrupeds, as perfect in their organization as the existing species of land quadrupeds, but most of them belonging to genera or species which are extinct. The tertiary strata are further remarkable for pre-

senting the frequent alternation of beds which contain the remains of marine animals, with other beds that contain the bones of land animals, or fresh-water shells.

The following are the principal substances contained in tertiary formations which have not been described.

CLAY AND MARLE.

Clay more frequently occurs in tertiary formations than in any other, but it often is found in alluvial and diluvial districts, and is, in many instances, evidently formed from the materials of pre-existing rocks or strata, which have been disintegrated and washed down into valleys that were once lakes. Many extensive beds of clay appear to be original formations, or at least are as much so, as the strata with which they are associated. Many of the varieties pass into each other.

The uses of clay are numerous and important, and too well known to require a description.

Clay is essentially of a variable proportion of siliceous and aluminous earth intermixed with sand; when it contains a considerable portion of calcareous earth, so as to effervesce with acids, it forms *Loam or Marle.* According to the greater or less prevalence of calcareous earth, the marle is denominated *Calcareous or Aluminous Marle.* The characteristic property of clay is to become plastic, or kneaded with water. Where the quantity of sand is considerable, this property is diminished. The more plastic clays are suited to the use of the potter; but as clay is generally mixed with the oxide of iron, and becomes red or yellowish-brown when burned, it is only those varieties which are nearly free from metallic matter, that

are employed for the finer kinds of pottery. When clay is much intermixed with sand, it is only suited for brick-making. Siliceous earth is almost always the prevailing ingredient in common clay; an admixture of twenty per cent. of alumin, is sufficient to form a kneadable clay. The hardness of clays is never great; they are easily cut by a knife, may in general be polished by friction with the finger nail, and are usually soft to the touch. Many kinds, when moistened, emit a peculiar odor, called *Argillaceous.*

The following varieties deserve notice.

Native Argill occurs in small, reniform masses, having the hardness of chalk and a dull fracture. It appears to be composed, when magnified, of very minute, prismatic, transparent crystals. Its color is pure white, is soft, but dry to the touch, yields an argillaceous odor, and adheres to the tongue. It seems to be almost a sulphate of lime.

*Collyrite** much resembles native argill. It has a very strong affinity for water, which it absorbs with a hissing noise, and becomes more or less translucent. It dries very slowly in the air, separates into prismatic masses, like starch, and loses about half its weight.

Porcelain Clay or Kaolin occurs in full, dull, friable masses, composed of fine particles slightly cohering. It is usually dry to the touch, and at the same time rather soft, but in some varieties it is a little unctuous. It has a slight adherence to the tongue. Its color is white, sometimes shaded with gray, yellow, or red. It readily absorbs water, and soon falls to powder; but, when pure, it is with difficulty formed into a ductile paste.

* Derived from the Greek, *kollurion*, from *koluo*, to check, and *reos*, defluxion.

*Cimolite** has for its original color a grayish-white; but by exposure to the air its surface becomes reddish. It has a texture inclined to slaty, and minute scales may sometimes be separated, leaving a smooth, resinous surface. It is somewhat difficult to break, yet it receives an impression from the finger nail. It adheres considerably to the tongue.

Adhesive Clay is, in general, very distinctly slaty, and the layers easily separate by the alternate action of dryness and moisture. Sometimes its slaty structure is imperfect, and the layers are undulated or irregular. It has a dull, earthy fracture, and adheres very strongly to the tongue. It is dry to the touch and very fragile. It is usually of a pale-gray color, sometimes nearly white, or with a tinge of red or green.

Potter's Clay is of a gray, white, or grayish-white color, but frequently the white or gray is shaded with yellow, blue, green, or red; sometimes it is dark-gray or brown, and often the shade of yellow, green, or red is considerably deep. It has sometimes a compact texture and is somewhat solid; in other cases it is more or less friable. It is smooth or a little unctuous to the touch, and when dry, receives a polish from the finger nail. Its fracture is dull, earthy, or uneven, and sometimes a little conchoidal. Some varieties have a structure more or less slaty. It adheres to the tongue, and emits an argillaceous odor, when moistened.

Pipe Clay is the purest kind of potter's clay. It is gray, grayish-white, or nearly white, and sometimes has a tinge of yellow. It is fusible, but becomes white when exposed to a great

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* Derived from *Cimolus*, an island in the Cretian Sea now Argentiera; on which this clay abounds.

heat, although in a more moderate heat it sometimes assumes a bluish-gray color.

Variegated Clay is tinged with different shades of white, red, and yellow, arranged in spots and stripes. Its structure is sometimes a little slaty.

Loam is nothing but potter's clay mixed with sand and oxide of iron, and sometimes with mica, or carbonate of lime. Its value in agriculture depends much on the proportions of its ingredients. It is sometimes called *Sandy or Clayey Loam.* When mixed with particles of decomposed vegetables, it is denominated *Mould.*

Sand.

The name of sand is given to all mineral matter which exists in minute, detached grains, and is denominated from the prevailing substance, as siliceous sand, iron sand, and so forth. Sand is generally formed from the disintegration of hard stones or rocks by the agency of water, and the particles of siliceous stones, possessing a greater degree of hardness than most other kinds. The greatest part of the sand which exists on the sea shore, or is spread on the surface of the earth, is siliceous. Argillaceous stones, or calcareous stones intermixed with alumin, when reduced to minute parts, form a kind of paste or mud; by intermixture with water, the particles unite or cement together as the mixtures become dry. When a bed of siliceous sandstone rises to the surface, the particles become separated by the action of the atmosphere and other causes, and form a loose, sandy soil; sometimes so destitute of mixture with other earths, as to be entirely unfit for vegetation. We are not to conclude, how-

ever, that all sand is the product of decomposed rocks; for a large portion of it is an original formation, particularly that which composes many sandstones.

Sand, principally composed of siliceous earth, is employed for numerous important uses. Mixed with quick lime it forms mortar. In the manufacture of pottery ware, a certain portion of siliceous sand is necessary to give it consistence, and to enable it to stand the action of fire. The further vitrifaction which the silex undergoes communicates a degree of hardness and solidity that pottery could not otherwise acquire. Siliceous sand is an article of prime importance in the manufacture of glass. When pure it forms the basis of the most beautiful, transparent flint and crown glass.

The following are the principal varieties of sand.

*Auriferous** *Sand* is generally of a blackish or reddish color, and ferruginous. From this circumstance, naturalists have concluded that the gold in these sands is derived from the decomposition of auriferous pyrites. The greatest part of the gold of commerce exists in small grains among the sands of rivers.

Green Sand or Copper Sand is an ore of copper, existing in small grains; it is composed of the metal combined with muriatic acid.

Iron Sand is an ore of iron, in very minute grains, which according to Werner, are not magnetic when at a depth in the earth, but becomes so by exposure to the atmosphere.

Volcanic Sand consists of minute grains, generally of a black color, thrown out of the craters of volcanoes in such immense quantities, as to darken the air, and cover the surface of the ground to a

* Derived from the Latin, *aurum*, gold.

vast extent with a new soil. It is sometimes crystalline. Towards the conclusion of an eruption, the sand changes its color, and is generally a white powder, improperly called ashes. It consists of white pumice, in a finely-comminuted state.

In reference to the various practical purposes to which sand has been applied, it has been sometimes distinguished into *Pit Sand*, *River Sand*, *and Sea Sand.*

CLASS VI.

Alluvial and Diluvial Depositions.

The disintegration of rocks and mountains is constantly taking place by the incessant operation of the elements; all bare and lofty cliffs and eminences are gradually wearing down; and the process will go on, until they are covered with the soil and vegetation, which protect them from further decay. Besides the causes which at present operate to reduce the most exposed and prominent parts of the earth's surface, and transport their materials into plains, or to the sea shore, there are evident indications of the destructive effects of ancient inundations, which have swept over the surface of the present continents, have excavated new valleys, torn off the summits of the loftiest mountains, and spread their ruins in immense fragments over distant regions. The sand, soil, or fragments, brought down by rivers, and spread along their banks, or at their mouths, are called *Alluvial Depositions.* The blocks of rock, and the beds of gravel spread or scattered on the surface of the ground, composed of stone, or fragments foreign to the districts in which they are

spread, and which frequently cover the bones of unknown species of quadrupeds, are called *Diluvial Depositions*, namely, depositions which have been formed by the deluge.

All the most fertile parts of the globe were formed by alluvial depositions: alluvial agency appears to have been the means employed in the economy of nature, to prepare the world for the residence of social and civilized man. The most ancient cities of which we have any authentic record, Babylon, Ninevah, and Thebes, were founded in the midst of alluvial soils, deposited by the Euphrates, the Tigris, and the Nile; indeed it does not appear unreasonable to believe, that the formation of soils for the support of vegetables and animals, was the final cause for which the world was created, and to which all terrestrial changes ultimately refer.

It has been justly observed by Dr. Paley and others, that in the peculiar conformation of the teeth in gramnivorous animals, and in the production of grasses which serve them for food, we may trace evident marks of relation, and of a designing intelligent Cause. With equal reason must we admit, that the destruction of mountains and the formation of soils for the support of the vegetable tribes are provided for by the same Cause, and are part of a regular series of operations in the economy of nature. Hence also may we infer, that those grand revolutions of the globe, by which new mountains or continents are elevated from the deep, are part of the same series, extending through ages of indefinite duration, and connecting in one chain, all the successive phenomena of the material universe.

By a wise provision of the Author of nature it is ordained, that those rocks which decompose

rapidly, are those that form the most fertile soils; for the quality of soils depends on the nature of the rocks from which they were formed. Granitic and sileceous rocks form barren and sandy soils; argillaceous rocks form stiff clay; and calcareous rocks, when mixed with clays, form marle; but when not covered by other strata, they support a short, but nutritious vegetation. For the formation of productive soils, an intermixture of three earths, clay, sand, and lime, is absolutely necessary. The oxide of iron appears also to be a requisite ingredient. The proportion necessary for the formation of good soil, depends much on the nature of the climate, but more on the quality of the subsoil, and its power of retaining or absorbing moisture. This alone may make a soil barren, which upon a different subsoil would be exceedingly productive. When this is the case, draining or irrigation offers the only means of improvement.

Besides the new land formed by alluvial depositions, beds of *Calcareous Tufa** are sometimes formed in valleys, and at the bottom of lakes, by a process which bears some analogy to chemical formations. Springs containing carbonic acid, which issue from limestone strata, contain particles of carbonate of lime chemically dissolved in the water; but on exposure to air and light, the carbonic acid, which had but a slight affinity for the particles of limestone, separates, and the particles of lime are precipitated and form calcareous incrustations. These in process of time form thick beds, and are sometimes sufficiently hard to be used for buildingstone. In almost all limestone countries, there are instances of calcareous incrustations formed in springs, which have received the name of *Petrifying Wells*.

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* Derived from the Italian, *tufo*, porous ground.

Peat is another substance which has been classed with alluvial soils, though it is obviously a vegetable production. It is found in various situations, often in valleys or plains, where it forms extensive, deep beds, from three to forty feet deep: it also occurs upon the sides of mountains; but even there, it is generally in a horizontal situation. Sometimes the tops of mountains, upwards of 2000 feet high, are covered with peat of an excellent quality. It is also found in situations nearly upon a level with the sea. Dr. M'Cullock, in his valuable History of the Western Islands of Scotland, has given a luminous description of the formation of peat, which completes the natural history of peat moss. Besides the *Sphagnum palustre*, he has enumerated nearly forty plants which concur to the generation of peat. The process by which these vegetables are converted into peat, is most clearly seen in the sphagnum. As the lower extremity of the plant dies, the upper sends forth fresh roots like most of the mosses, the individual thus becoming in a manner immortal, and supplying a perpetual fund of decomposing vegetable matter. A similar process, though less distinct, takes place in many of the rushes and grasses, the ancient roots dying together with the outer leaves, while an annual renovation of both, perpetuates the existence of the plant; the growth of peat, necessarily keeps pace with that of the vegetables from which it is formed. Where the living plant is still in contact with peat, the roots of the rushes, and ligneous vegetables, are found vascillating between life and death in a spongy, half-decomposed mass. Lower down, the pulverized, carbonaceous matter is seen mixed with similar fibres, still resisting decomposition. These gradually disappear, and at length, a finely-powdered substance alone

is found, the process being completed by the total destruction of all organized bodies. The best peat is that of which the decomposition is the most complete, and the specific gravity and compactness the greatest.

Peat is much used for fuel in countries where wood and coal are scarce.

CLASS VII.

Volcanic Rocks.

Lava.

Lava* is formed by subterranean fire, and thrown in a melted state, out of extensive fissures made in the crust of the globe by heat, or is poured out of the craters of volcanoes. These currents of melted earthy matter are either spread over the bottom of the sea, or on the surface of islands and continents. When cool, they form rocks and stony beds of considerable extent and thickness. The upper surface of these beds is generally more or less vesicular and scoriaceous, and it is only where they are broken through, that the compact state of the lava can be seen. From this circumstance the volcanic origin of compact lava has frequently been doubted, as it was supposed that all lava must be porous; but it has been well observed, that to judge of the substance of a current of lava from what appears on the surface, would be like judging of a vat of wine, from the froth with which it was covered. From the observations of M. Cordier, on lava and other earthy, volcanic products, it appears that they are compos-

* Derived from the Latin, *lavo*, to wash or flow.

ed of a congeries of minute crystals, or grains of different minerals; and he further found, that all volcanic rocks are composed of similar crystalline grains, interlaced with each other, and these grains or crystals are of the same kind as the larger crystals often imbedded in lava. The whitish grains are either felspar, leucite, or olivine; the dark-green are augite or hornblende. The black and opaque grains are iron sand, consisting of grains of iron and titanium. Grains of micaceous iron are scarce; they yield a red powder when pulverized.

The two minerals, felspar and augite, compose the greater part of the mass. According to the prevalence of felspar, the lava possesses different characters. Lava which contains from forty-five to fifty per cent. of felspar melts into black glass; black basalts are of this kind. If the felspar exceed fifty-five per cent. and is under seventy, it melts into a bottle-green enamel. Such are the greenish and grayish lavas. When the felspar is in proportion of ninety per cent. it melts into a white opaque or translucent glass. This forms the petro-sileceous lavas, called sometimes *Compact Felspar or Clinkstone.* All lava may therefore be divided into two kinds, that which melts into white glass, and that which melts into black glass. The former, called by Cordier, *Leucostine*, comprises those substances called by Dolimieu, *Petro-siliceous Lava*; by Haüy, *Compact Sonorous Felspar*; by Werner, *Clinkstone.* It also appears to comprise some of the harder varieties of claystone. The lava which melts into a dark glass comprises the dark-colored varieties and basalts.

This view of the subject tends greatly to simplify our arrangement of volcanic products, as all the earthy masses or rocks formed by volcanoes,

however differing in structure, density, or color, are to be regarded only as different aggregations of the same simple minerals.

Though different lavas are composed of nearly the same ingredients, they are often so variously modified by the different degrees of heat to which they have been subjected, and the circumstances attending their cooling, that no concise mineralogical description can be given, which will agree with all the varieties of lava.

Light-colored stony lava sometimes occurs in a nearly vitrified state, resembling the opaque white glass frequently formed in glass furnaces, when the substance has been cooled slowly.

Dark-colored stony lavas pass through all the various shades, from a gray to a black, and from the various states of vesicular and porous to compact; from compact they pass into a semi-vitrified state, and from thence to obsidian or black volcanic glass. On examining the lavas with a powerful lens, it will be seen that they are composed, as Cordier has described, of minute crystals, or grains of different minerals; and they frequently contain imbedded crystals or grains of larger size, either of augite, leucite, olivine, or basaltic hornblende.

The currents of very ancient lavas are frequently compact. These lavas were probably formed when the present continents were covered by the ocean, and were therefore subjected to a high degree of pressure when in a melted state. Some lavas have been found containing marine shells.

The following are the principal varieties of lava.

Vesicular Lava, Scoriæ, or Slagg* can only be regarded as different forms of lava, tumefied by

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* Derived from the Greek, *skoria*, rejected matter; that which is thrown off.

heat suddenly refrigerated. The scoriæ or slagg generally presents a semi-vitrified appearance.

Volcanic Glass appears to be formed by some peculiar circumstance attending the cooling of the lava; for it is well known, that lava and basalt form glass, when melted and suddenly cooled; and that the same glass when remelted and slowly cooled forms stone.

Obsidian or Dark Volcanic Glass appears to pass into pitchstone. It yields either a black or white glass before the blowpipe, according to the prevalence of felspar or augite; it may be traced in some instances to where it passes into compact basalt or lava; in other instances, it may be seen passing into pumice.

*Pumice** may be regarded as a very light, spongy lava, varying in porosity, in texture, and in color. It appears to be the product of intense heat, operating either on lava or obsidian, and reducing it to a capillary or fibrous state. The light-colored pumice is formed of lava or obsidian abounding in felspar. Lava and obsidian swell greatly when they are exposed to the action of intense heat, a quantity of gas appearing to be evolved. The evolution of this gas gives to the soft, tenacious paste the light and porous form of pumice. In some of the pumice of Lipari, the pores are too small to be seen without a lens. The pumice is, however, sufficiently light to swim in water.

Pumice occurs in beds and masses; it has an irregular, fibrous structure, with elongated cells or pores; the lustre is shining and pearly in the direction of the fibres the colors are very light-gray passing into smoky-gray. It is harsh to the touch, and fusible. Like other volcanic and basaltic

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* Derived from the Latin, *spuma*, foam.

rocks, it consists of silex, with a portion of alumin, potash, or soda. Pumice is often thrown up by submarine volcanoes, and floats on the surface of the ocean, and has been seen at a distance of more than a hundred miles from land.

Pumice is used for polishing glass and metals, and for various other purposes.

Volcanic Tufa appears to be formed of the loose sand or powders, together with smaller fragments of lava, which have become consolidated by water and pressure. In some instances, the tufa may have been formed by the volcanic powders and water intermixed, and thrown out in the form of mud.

Terras and Pouzzolani are soft, ferruginous tufas, which possess the property of consolidating, when mixed with a portion of lime, and employed as a cement.

CLASS VIII.

Meteoric Stones or Meteorolites.

The descent of stones from the atmosphere is a fact of which we have now abundant and satisfactory evidence. Numerous instances of this kind are recorded by ancient historians, but more accurate and circumstantial descriptions of the phenomena attending the descent of these stones, may be found in the scientific journals published in the various parts of Europe and America within these last forty years. Still more satisfactory evidence is furnished by the external characters and the analyses of these stones, for however distant the part of the world in which they have fallen, they bear, for the most part, a striking resemblance to

each other, and contain nearly the same constituent parts. In many instances, brilliant meteors have been observed moving with great velocity in a horizontal direction, exploding with a loud report, and discharging stony masses, which fell to the earth in an ignited state. Some meteors have been observed to explode repeatedly, and discharge a great number of stones in various parts; others appear to be extinguished by a single explosion. A rushing or whizzing sound has been generally heard as the meteor passed near the zenith of the observer; and from numerous observations of the same meteors made at the same time in distant parts of the country, it is evident, that they pass through very elevated regions of the atmosphere.

In some instances, the appearance of a black or gray cloud has been observed moving through a clear sky, from which stones have been discharged.

Some philosophers conjecture that these stones have been projected from volcanoes in the moon;* others, that they are bodies revolving in space, composed of the earths in a metallic state, and that they take fire and explode when they come within the atmosphere of the earth. A more probable opinion is, that the different materials of which these stones are formed, are supposed to exist in an elementary and gaseous state, and to combine and explode, forming stony masses, and at the same time evolving light and heat. The instantaneous formation of masses of ice in the atmosphere in the time of thunder storms may perhaps elucidate the formation of meteoric stones. Were the tem-

* La Place has proved by strict mathematical calculation, that a mass, if projected by a volcano from the moon, with a velocity of about a mile and a half per second, which is possible to be done, it will thence be thrown beyond the sphere of the moon's attraction, and into the confines of that of the earth; the consequence of which would be, that the mass must directly fall to the earth and become a part of it.

perature of the earth permanently below the freezing point, these masses would remain as solid stones on its surface.

Meteoric stones have the following characters. Their form is oblong or roundish; they vary in weight from a few ounces to some hundred pounds.* Externally they are covered with a black incrustation, which is generally composed of the oxide of iron; internally the color inclines to ash-gray, sometimes intermixed with dark-brown, so that its aspect at first sight resembles a coarse sandstone. The grains are brown and opaque, intermixed with particles of metallic iron and iron pyrites, cemented by a light-gray, earthy matter, which is sometimes so soft as to admit of the easy separation of the imbedded grains.

CLASS IX.

Coral Reefs and Islands.

In consequence of the numerous situations where these are observable in the Pacific Ocean and Indian Seas, very exaggerated ideas have generally been entertained of their relative importance. Large masses supposed to be the work of myriads of polypi,† were considered to have been raised by the labor of these animals from great depths, while immense sheets of coral rock were supposed to cover the bottom of the seas. These minute animals raise up walls and reefs of coral rock with astonishing rapidity in tropical climates, and encircle the present islands with belts of coral,

* A stone fell near Verona in 1762 weighing 300 pounds.

† Plural of *polypus*, derived from the Greek, *polus*, many, and *pous*, a foot.

thus enlarging their coasts. A coral reef of seven hundred miles in length, extends from the north-west of Australasia towards New Guinea. For a detailed account of coral rocks and reefs, see the Observations of Dr. Forster, and the Voyages of Captain Flinders, and of Kotzebue. The French naturalists, M. M. Quoi and Gaimard have, however recently shown, that madrepores which form coral rocks, do not commence their operations at greater depths than twenty-five or thirty feet below the surface of the sea. They construct their habitations on the summits of submarine rocks, and increase their height, but do not form them. The quantity of calcareous matter which these animals furnish, cannot be compared with the quantity of materials which testaceous animals have furnished, and still continue to furnish, to the crust of the globe.

CHAP. III.

Superficial Distribution of Land and Water.

The relative proportion of dry land to the ocean, as it at present exists, is such, that nearly three-fourths of the whole surface of the globe may be assigned to the latter. Of the former, the configuration is very various, presenting the greatest surface in the northern hemisphere. Although the land sometimes rises high above the level of the sea, according to our general ideas on such subjects, it is, in reality, but slightly removed above that level, when considered, as it should be,

with reference to the semi-diameter of the earth. The superfices of the Pacific Ocean alone is estimated as somewhat greater than that of the whole dry land with which we are acquainted. Dry land can only be considered as so much of the rough surface of our globe as may happen, for the time, to be above the level of the waters, beneath which it may again disappear, as it has done at the different previous periods. La Place calculated that the mean depth of the ocean was a small fraction of 10 miles, while it has been variously estimated by others at between 2 and 3 miles. The mean height of the dry land above the ocean-level does not exceed two miles but probably falls far short of it;* therefore assuming two miles for the mean depth of the ocean, the waters occupying three fourths of the surface of the earth, the present dry land might be distributed over the bottom of the ocean, in such a manner that the surface of the globe would present a mass of waters—an important possibility, for, with it at command, every variety of the superficial distribution of land and water may be imagined, and consequently every variety of organic life, and each suited to the various situations and climates under which it would be placed.

The surface of the crust of the globe is so uneven, that the ocean, preserving a general level, enters among the dry land in various directions, forming what are commonly termed *Inland Seas;* such as the Baltic, Red, and Mediterranean seas, in which geological changes may be effected different from those in the open ocean.

Bodies of salt water are sometimes included in the dry land, which have been called *Caspians,* from the Caspian Sea, the largest of them. These have no known communication with the main

* Mount Dawalageri is estimated to be 27677 feet in height.

ocean; indeed the level of the Caspian is represented as much lower than that of the Black or Mediterranean Seas. They have been variously accounted for, some supposing that they have been left isolated by a change in the relative level of land and water; while others imagine their saltness to arise from their occurrence in countries impregnated with matter partaking of the properties of salt. It is stated, in support of the latter opinion, that the Caspian, and the lakes, Aral, Baikal, and others, are situated where salt springs abound. Whatever may be their origin, it will be obvious, that if the fresh water they receive be not equal to their evaporation, they will become gradually more salt, until, the water being saturated, the surplus salt will be deposited at the bottom, and layers of it will be formed of a size and depth proportioned to those of the lake or sea.

It will be out of place to attempt a general description of all the various combinations of land and water, with which all must be more or less familiar; but it may be necessary to notice that fresh-water lakes cover very considerable spaces, and that thus, even at present, very extensive deposites may take place, which can only envelope the remains of land or fresh-water animals and vegetables.

CHAP. IV.

Temperature of the Earth.

The superficial temperature of our planet is certainly very materially influenced by, if it may not be entirely due to, solar light and heat. That the difference of seasons, and of the climates of various latitudes, originates in the greater or less exposure to the sun is obvious. That local circumstances cause great variations of superficial temperature, is also well known; yet the principle seems to prevail, that, under equal circumstances, the temperature decreases from the tropics to the poles.

According to Arago, 'in no part of the earth or land, and in no season, will a thermometer raised from two to three metres* above the ground, and protected from all reverberation attain the 46th centigrade degree.† In the open air, whatever be the place or season, the temperature of the atmosphere never attains the 31st centigrade degree. The greatest degree of cold which has ever been observed upon our globe, with the thermometer suspended in the air, is 50 centigrade degrees below the freezing point. And the temperature

* A metre is the standard measure of distance in France, which is equal to 39.37 English inches; or .0000001 part of the distance from the equator to the north pole.

† When we consider the simplicity of the centigrade thermometer, and the facilities with which calculations can be made with it, it seems strange that its use should not be generally adopted in this country. It can easily be reduced to that of Fahrenheit, by considering that the latter is to the former, between the freezing and boiling points of water, as 180 to 100, or as 9 to 5. The degrees of Reaumur's scale are to those of Fahrenheit's, as 4 to 9.

of the water of the sea, in no latitude, and in no season, rises above 30 centigrade degrees.'*

Geologists have discovered that the superficial temperature of the earth has not always remained the same, and that there is evidence of a very considerable decrease, which may arise either from external, superficial, or internal causes.

External Influence. Heat, it has been supposed that a difference in the relative position of our planet and our great luminary, would cause a corresponding change in the surface-temperature of the globe. Theories have been invented which suppose such a change in the axis of the earth as would render the present poles parts of the equator, and thus capable of having once supported a tropical vegetation, which has gradually disappeared, and been replaced by such plants as can exist amidst masses of ice and snow. Herschel, viewing this subject with the eye of an astronomer, considers that a diminution of the surface-temperature might arise from a change in the ellipticity of the orbit of the earth, which, though slowly, gradually becomes more circular. No calculations having yet been made as to the probable amount of decreased temperature from this cause, it can at present be only considered as a possible explanation of those geological phenomena which point to considerable alterations in climates.

Superficial Influence. A decrease of temperature may arise from such a variation in the relative position of land and water, and in the elevation and form of land, as may cause the climate in any given position on the surface of the earth, so to change, that a greater heat may precede a less heat, and the land be capable of supporting the

* Ann. de Phys. et de Chim. tom. xxvii.

vegetables and animals of hot climates at one time, and be incapable of doing so at another.

Internal Influence. From the earliest times an opinion has existed among philosophers that a central heat exists — an opinion naturally arising from the phenomena of volcanoes and hot springs. But, notwithstanding this opinion, it was not until a comparatively late period that direct experiments were instituted, for the purpose of determining whether the temperature, does, or does not, increase with the depth, or from the surface downwards. The probability of this theory seems to rest, first, on the experiments made in mines,* which, notwithstanding their liability to error from various sources, still seem to show, particularly those made in the rock† itself, and increase of temperature from the surface downwards; secondly, on thermal or hot springs,‡ which are not only abundant among active and extinct volcanoes, but also among all varieties of rocks, in various parts of the world; thirdly, on the presence of the volcanoes themselves, which are distributed over the globe, and present such a general resemblance to each other, that they may be considered as produced by a common cause, and that cause, probably, deep-seated; and fourthly, on the terrestrial temperature at comparatively small depths, which do not coincide with the mean temperature of the air above it.

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* Humboldt ascertained by experiment, that the temperature of the springs of the Guanaxuato silver mine at the depth of 522 metres, was 35 .8 degrees above zero, while the mean temperature of the country was only 16 degrees above.

† According to Fox's experiments in 1822, in the Cornwall mines, England, the temperature of the rock at the depth of 421 metres was 24 .2 centigrade degrees above zero, while the mean temperature of the country was only 10 centigrade degrees above.

‡ The celebrated Geysers of Reikum in Iceland have been known, with a temperature of 112 degrees F., to rise and fall, and dash up spray to the height of 20 or 30 feet.

The temperature at the bottom of seas* and lakes is not at variance with probability, as the waters merely arrange themselves according to their greatest specific gravity; and this would take place whether the earth was, or was not, heated towards the centre. The temperature of the earth, to a small depth immediately beneath a mass of sea, is also likely to be the same as that of the greatest density of the water, so constantly present to it.

Neither is the probability of internal heat at variance with the figure of the earth or observed geological phenomena. The figure of our planet being that which a fluid body would assume if revolving in space, it is as probable that this fluidity should be igneous or aqueous. Geological phenomena attest the irruptions of igneous matter from the interior at all periods; as also elevations of mountains and great dislocations of the surface of the earth, caused by forces acting from beneath; and finally, a great decrease of surface-temperature. Should we be inclined to build a theory on the probability of a central heat, we may suppose, as has often been done, that our world is a mass of igneous matter in the act of cooling.

Baron Fourier considered, from the form of the earth, the disposition of the internal layers, shown by experiments with the pendulum, to increase in density with their depth, and from other considerations, that it seemed proved that a very intense heat formerly penetrated all parts of our globe.

* Scoresby found by experiment in Lat. 79 degrees 4 minutes N. and Long. 5 degrees 4 minutes E. that at the depth of 400 fathoms the thermometer stood at 36 degrees above zero, while at the surface it stood only at 29 degrees above. On the contrary, De la Beche tried the temperature of Lake Thun in Switzerland, in May 1820, and found, that at the surface of the lake the thermometer stood at 60 degrees above zero and at the depth of 105 fathoms it stood only at 41 5 degrees above.

He concluded that this temperature was dissipated into the surrounding planetary spaces, the temperature of which he concluded from the laws of radiant heat to be equal to 50 centigrade degrees above zero or 90 degrees F. He moreover inferred that the earth had nearly reached its limit of cooling. The original heat contained in a spheroidal mass equal in magnitude to our globe, would diminish more rapidly at the surface than at great depths, where the elevated temperature would remain for a great length of time. He further inferred from these circumstances, and from the temperature of mines and springs, that there is an internal source of heat, raising the temperature of the surface above that which the action of the sun could alone give it.

CHAP. V.

VOLCANOES.

VOLCANOES* are openings made in the earth's surface by internal fires; they regularly, or at intervals, throw out smoke, vapor, flame, large stones, sand, and melted stone called *lava*. Some volcanoes throw out torrents of mud and boiling water. Volcanoes most frequently exist in the vicinity of the sea or large lakes, and also break out from unfathomable depths below the surface, and form new islands and reefs of rock. When a

* Derived from the heathen deity, *Vulcan*, who is poetically related to have had his forge in Mount Ætna, where his workmen, the Cyclops, made thunderbolts.

volcano breaks out in a new situation, it is preceded by violent earthquakes, the heated surface of the ground frequently swells and heaves up, until a fissure or rent is formed, sometimes of vast extent. Through this opening, masses of rock with flame, smoke, and lava, are thrown out, and choke up part of the passage, and confine the eruption to one or more apertures, round which conical hills or mountains are formed. The concavity in the centre is called the *crater*. The indications of an approaching eruption from a dormant volcano are, an increase of smoke from the summit, which sometimes rises to a vast height, branching in the form of a pine tree. Tremendous explosions, like the discharge of artillery, commence after the increase of smoke, and are succeeded by red-colored flames, and showers of stones. At length the lava flows from the top of the crater, or breaks through the sides of the mountain, and covers the neighboring plains with melted matter, which, becoming consolidated, forms a stony mass, often not less than some hundred square miles in extent, and several yards in thickness. The eruption of lava has been known to continue several months. Intensely black clouds composed of a kind of dark-colored sand or powder, improperly called ashes, are thrown from the crater after the lava ceases to flow, and sometimes involve the surrounding country in total darkness at noon-day. Towards the conclusion, the color of the volcanic sand changes to white. It consists of pumicestone in a finely-comminuted state.* When the lava flows freely, the earthquakes and explosions become less violent; which proves that they were occasioned by the confine-

* During an eruption of Ætna, a space of 150 miles in circuit was covered with a stratum 12 feet thick.

ment of the erupted matter both gaseous and solid. The smoke and vapor of volcanoes are highly electrical.

Various theories have been formed for the explanation of volcanic phenomena; but it must be confessed, that they are all more or less defective, and that the real causes of such phenomena are mere subjects of conjecture. With some of the effects we are familiar; though with the districts most ravaged by erupted matter, we are far from being well acquainted; our principal knowledge of volcanoes being derived from the two largest active volcanoes of Europe, Ætna and Vesuvius, but principally from the latter. Ætna certainly covers a considerable surface, but Vesuvius sinks into insignificance before some of the great volcanoes of the world.

From the various phenomena which volcanoes present, we may with probability infer, that the internal part of our planet, is either wholly or partially in an igneous state, however difficult it may be to explain in what manner this heat is generated and confined. In every department of nature, our inquiries are terminated by ultimate facts, beyond which further research becomes vain. The constant generation and emission of light from the surface of the sun is more inexplicable and surprising, than the constant generation of heat in the centre of our planet; but we cannot refuse our consent to the fact, though it is beyond the power of the human mind to conceive, by what means the particles of light are propelled through space with such astonishing velocity.* We are too apt to measure natural operations by their coincidence with the received systems of philosophy,

* The rays of light are about 8 minutes in passing from the sun to the earth, the distance being about 95000000 miles.

and to make our own ignorance the standard of truth. Had all the volcanoes in the world been dormant for the last two thousand years, and were we acquainted with their existence only by the writings of ancient historians, we should discredit the fact, and prove its impossibility by an appeal to established chemical principles; we should further accompany the proof with a pathetic lamentation over the credulity of former times. The descent of stones from the atmosphere was denied during a longer period, though the fact is now established beyond all doubt.

Admitting the existence of central fire in the earth, it is not difficult to conceive, that there may be determinate causes, by which its intensity is increased or diminished at certain periods. We know but little respecting the operations of electric or Voltaic energy in the laboratory of nature, but from the existence of electric light at the poles, we may infer that electric currents are passing through the earth, and are important agents in many subterranean phenomena. Perhaps the different beds of rock, which environ the globe may act like a series of plates in the Voltaic pile, and produce effects commensurate with their vast magnitude. Voltaic energy is capable of supporting the most intense degree of heat without access to atmospheric air, or even *in vacuo;* and this for an indefinite time.

Whatever origin we ascribe to subterranean fire, there can be no doubt that it will make its way through the surface in those places where the incbmbent rocks offer the least resistence, or where they are the most fusible. By the access of water to this fire, the sudden evolution of steam, hydrogen gas, and many phenomena of volcanic eruptions, will admit of an easy explanation. Most of the

volcanoes being situated near the sea or great lakes, we may infer that water is, in some way, necessary to the production of volcanic phenomena.

It is an acknowledged fact, that 'Nature does nothing in vain;' and can we suppose that the interior part of the earth is constructed with less skill, than what is evinced in the organization of the simplest animal or vegetable? Or, when we contemplate our planet pursuing its trackless path through the heavens with unerring precision, can we believe, that its internal motions are not governed by determined laws, destined to answer the most important purposes in the economy of nature?

Though we are inclined to regard the cause of volcanic origin to be electric or Voltaic energy, as consonant with existing facts, yet it is contradictory to most of the theories hitherto advanced. We would, however, willingly adopt any other explanation which may afford a more satisfactory solution. The Roman poet,* after conducting his hero through the subterranean abodes, dismisses him through the Ivory Gate; and should our readers infer from these speculations respecting the subterranean operations of nature, that we treat them in a similar manner, it will not occasion disappointment. Embarked with them in a voyage of discovery, we shall gladly hail the signal for the appearance of a new world, whoever the fortunate discoverer may be.

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* Æneas.

CHAP. VI.

Earthquakes.

The connexion between volcanoes and earthquakes is now so generally admitted that it would be useless to enumerate the various circumstances which point to this conclusion. They both seem the effects of some cause as yet unknown to us. The motion of the ground produced by earthquakes is not always the same; sometimes resembling the undulatory movement of a heavy swell at sea, though much quicker, and being at others tremulous, as if some force shook the ground violently in one spot. The former of these is far the more dangerous, as it forces walls and buildings off their centres of gravity, crushing whatever may be beneath them.

It has been considered that earthquakes are presaged by certain atmospheric appearances, but it may be questionable to what extent this supposition is correct. Historians of earthquakes seem to have been generally desirous of producing effect in their descriptions, adding all that could tend to heighten the horror of the picture. They have not always, moreover, been anxious or able to separate accidental from essential circumstances. As far as our own experience goes, which is however merely limited to a few earthquakes, the atmosphere seemed little affected by the movement of the earth; though we would be far from denying that it may be so; for we can scarcely imagine such movements to arise in the earth, without some modification or change of its usual state of electricity which would affect the atmosphere. If

animals be generally sensible of an approaching shock, it might arise as well from electrical changes as from the sounds which they may be supposed capable of distinguishing.

Earthquakes very frequently precede violent volcanic explosions, even though they may be felt far from a fiery vent. Thus, the great earthquake which destroyed the Caraccas, March 26, 1812, was followed by the great eruption of the Souffrier in St. Vincents, on April 30th of the same year; when, according to Humboldt, subterranean noises were heard the same day at the Caraccas and on the banks of the Apure.

Earthquakes are felt over very considerable spaces, and of this no better example has yet been recorded than the celebrated earthquake of Lisbon in 1755, the shock of which was felt over nearly the whole of Europe, and even in the West Indies.

The force capable of causing such extensive vibrations must have been very considerable; and, with every allowance for the easy transmission of motion and sound laterally through rocks, must have required considerable depth for its production. Motion seems always to be communicated to water during earthquakes, the vibratory movement being very frequently felt by vessels at sea, and waves of greater or less magnitude, according to the force of the shock, being commonly driven on shore. The waves produced during the great Lisbon earthquake rose sixty feet high at Cadiz, and eighteen feet at Madeira, causing various movements of the water on the coasts of Great Britain and Ireland. Similar waves, though of proportionally less size, are common during volcanic eruptions; motion being produced in the surrounding water, which being unable to rend and crack like the land, communicates the impulse it has received to the

waters around, and thus a wave is propagated which will diminish in height in proportion as it recedes from the disturbing cause. In almost all ports irregularities in the motion of the sea are at times observable, which cannot be reconciled with the tides or motions communicated to water by temporary currents or winds in the offing.

It may also be remarked that rocks would transmit sounds unequally from variations in their texture and continuity, and that subterranean noises might be audible while the shock which produced them could not be distinctly felt. Various sounds are recorded as accompanying earthquakes, but the most general seems a low rumbling noise like that of a wagon passing rapidly along. 'The first shock I ever experienced,' says De la Beche, 'was during a beautiful night, on the north side of Jamaica, when it appeared as if a wagon, rolling rapidly to the house, gave it a smart rap and then passed on.'

It has been considered, and with much probability, that the very great distances at which volcanic explosions from surface-vents have been heard, arises from the transmission of the sound through the rocks. The great explosion at Sumbawa, is described as having been heard in Sumatra, a distance of 970 geographical miles, and at Ternate, 720 miles in another direction. It is also stated that the eruption from the Aringuay, in the island of Lucon, Philippines, in 1641, was heard in Cochin-China.

Earthquakes produce changes in the level of the land, raising and depressing ground, and causing clefts, slips or faults, and various other modifications of surface. The raising of the surface implies either an expansion of the solid matter beneath, or a separation of parts, which should form

a cavity, filled either by gaseous or liquid substances. We are not aware of anything that could produce the expansion required but heat, so that if the temperature were again diminished, contraction would ensue. If a separation of parts were effected, and the upper portion raised, the gaseous or liquid support could scarcely be considered permanent, unless the injected matter became solid, as might happen with liquid lava, and the hollow produced by such injection be far removed from the surface.

The best example of the bodily elevation of land with considerable surface appears to be that recorded by Mrs. Maria Graham, as having taken place during the Chili earthquake of 1822. The shock extended along the coast for more than a thousand miles, and the land was raised for a length of one hundred miles, with an unknown breadth, but certainly extending to the mountains. The beach was raised about three or four feet, as was also the bottom near the shore ; on the former shell fish were still adhering to the rocks on which they grew. It was also observed that there were other lines of beach, with shells intermixed, above that newly elevated, attaining in parallel lines a height of about fifty feet above the sea ; seeming to show that other elevations of the same land had been effected by previous earthquakes. During this earthquake the sea flowed and ebbed several times. No visible change in the atmosphere was produced previous to the shocks, but it is supposed that some effect, perhaps electrical, may have been caused by the earthquake, for the country was subsequently deluged by storms of rain.

Mr. Lyell has accumulated a considerable mass of evidence to show that such elevations have been the consequence of earthquakes in other places,

and that considerable depressions have also occurred. Thus, during the Cutch earthquake of 1819, the eastern channel of the Indus was altered, the bed of which was in one place deepened about seventeen feet, so that a spot once fordable became impassable.

A variety of surface changes was effected during the great earthquake in Calabria in 1783. Of these a summary has been given from various authorities by Mr. Lyell, whose account will be perused with interest, however little we may feel inclined to adopt the theoretical conclusions that have been deduced from it. The earth had a waving motion; numerous and deep rents were formed; faults were produced, even through buildings; large landslips took place; lakes were formed, — one about two miles long by one broad, from the obstruction of two streams; the usual agitation of the neighboring sea was produced, and heavy waves broke upon the land, sweeping all before them.

The great earthquake in Jamaica of 1692, generally described as having swallowed up Port Royal, has been adduced as an example of great derangement. By a careful perusal of the statements made, and an examination of the places said to have been most affected, the accounts appear to have been much exaggerated; nor need this surprise us, when we reflect how difficult it is to elicit truth respecting natural phenomena, from those who have been dreadfully alarmed by them. The narrow spit of land, terminated by the present town of Port Royal, is a sand bank some miles long, thrown up, apparently, by the sea. The great mischief done at Port Royal seems to have been occasioned by a heavy wave, such as generally accompany great earthquakes, which rushed

into the town, then, as at present, elevated but a few feet above the level of the water, sweeping away all within its influence.* Rents also appear to have been formed, and there may have been subsidence, though it must have been somewhat difficult to find chimney-tops in Port Royal for the masts of wrecked vessels to appear among, such conveniences being confined to little low and detached kitchens where their presence may be required. The accounts also of submerged standing houses must be received with some caution, particularly when it is recollected that a frigate was driven by the force of the water over their tops.

Funnel-shaped, or inverted conical cavities are by no means unfrequent on plains after earthquakes, and are so much alike wherever they occur, that they must have some common cause for their production. Circular apertures were produced in the plains of Calabria by the earthquake of 1783: they are described as commonly of the size of carriage wheels, but often larger, and smaller; they were often filled by water, but more frequently by sand. Water seems to have spouted through them. During the earthquake in Mercia in 1829, numerous small, circular apertures were produced in a plain near the sea, which threw out black mud, salt water, and marine shells. After the earthquake at the Cape of Good Hope, in Dec., 1809, the sandy surface of Blauweberg's Valley is described as studded with circular cavities, varying from six inches to three feet in diameter, and from four inches to a foot and a half in depth. Jets of colored water are stated, by the inhabitants of the valley, to have been thrown out of these holes to the height of six feet during the

* If a great earthquake were to produce a wave from 10 to 20 feet high, it would sweep away the greater part of the present Port Royal.

earthquake. It seems somewhat difficult to account for these appearances, though the common aqueous discharges through rents or chasms can be more readily understood. During the Chili earthquake, previously noticed, sands were forced up in cones, many of which were truncated with hollows in their centres.

The courses of springs are, as would be anticipated, often deranged amid such motions of the ground; and flashes of light, or bright meteors, are so frequently mentioned that we can scarcely doubt their occurrence, and they may, perhaps, be considered as electrical.

If we now withdraw ourselves from the turmoil of volcanoes and earthquakes, and cease to measure them by the effects which they have produced upon our imaginations, we shall find, that the real changes they cause on the earth's surface are but small, and quite irreconcilable with those theories which propose to account for the elevations of vast mountain ranges, and for enormous and sudden dislocations of strata, by repeated earthquakes acting invariably in the same line, thus raising the mountains by successive starts of five or ten feet at a time, or by catastrophes of no greater importance than a modern earthquake. It is useless to appeal to time: time can effect no more than its powers are capable of performing: if a mouse be harnessed to a large piece of ordnance, it will never move it, even if centuries on centuries could be allowed; but attach the necessary force, and the resistance is overcome in a minute.

VOCABULARY.

Amorphous. Having no determinate form; of irregular shape.
Attenuate. To comminute; to break or wear solid substances into finer or very minute parts.
Bivalve. Having two shells or valves.
Columnar. Formed in columns; having the form of columns.
Comminution. The act of reducing to a fine powder or to small particles; pulverization.
Conchoidal. Resembling a conch or marine shell; having convex elevations and concave depressions, like shells, as a *conchoidal fracture.*
Concretion. The process by which soft or fluid bodies become thick, consistent, solid or hard; the act of growing together, or of uniting by other natural process, the small particles of matter into a mass; to become solid by congelation, condensation, coagulation, or induration.
Congeries. A collection of several particles or bodies in one mass or aggregate.
Decrepitate. To crackle as salts when roasting.
Deliquesce. To become fluid.
Dendritic. Containing the figures of shrubs or trees.
Disintegrate. To separate the integrant parts of a mass.
Friable. Easily reduced to powder.
Fusible. Capable of being melted.
Hexagonal. Six-sided.
Lamellar. Disposed in thin plates or scales.
Lenticular. Of the form of a lens.
Ligneous. Partaking of wood.
Nodule. A little knot or lump.
Nodular. In the form of a nodule or knot.
Nucleus. A kernel; something about which matter is collected.
Opaque. Impervious to the rays of light; not transparent nor translucent.
Pass. *To pass into*, to unite and blend, as two substances or colors, in such a manner that it is impossible to tell where one ends or the other begins, as one rock *passes* into another.
Pseudo-metallic Lustre is that which is perceptible only when held towards the light.
Reniform. Having the form or shape of the kidneys.
Rhomboidal. Having the shape of a rhomboid, or of that approaching to it.
Scoriaceous. Pertaining to dross; like dross or the recrement of metals; partaking of the nature of scoria.
Set. To congeal or concrete.
Stalactic. Having the form of icicles.
Strata. (Plural of *stratum.*) Beds, layers; as *strata* of sand, clay, or coal.
Translucent. Transmitting rays of light, but not so as to render objects distinctly visible.
Transparent. Having the property of transmitting the rays of light so that bodies can be distinctly seen through; pervious to light; opposed to *opaque.*
Tumefy. To swell; to rise in a tumor.
Vesicular. Pertaining to vesicles; hollow; full of interstices.
Vitrify. To become glass.